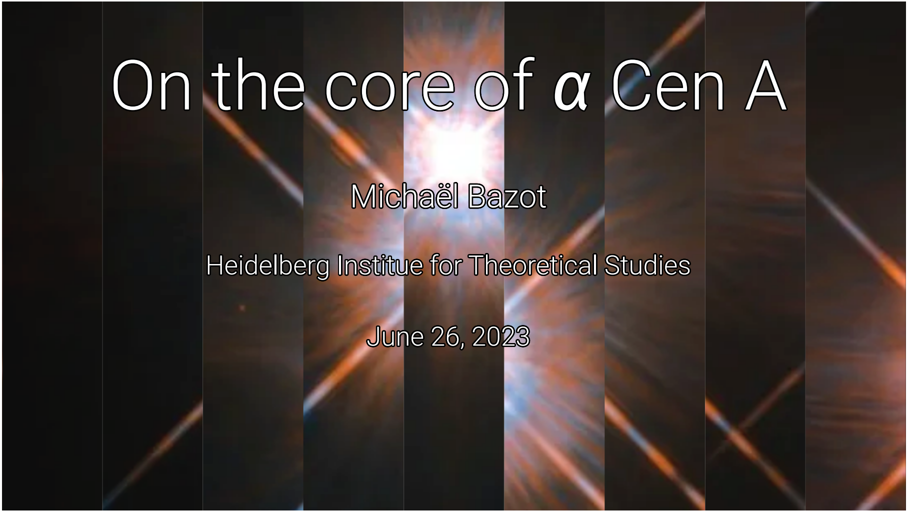


On the core of α Cen A

Michaël Bazot

Heidelberg Institue for Theoretical Studies

June 26, 2023

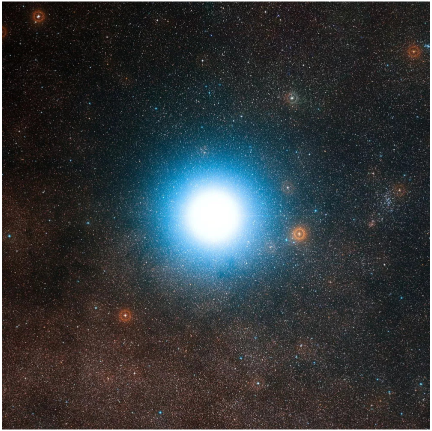
α Cen A (and its core)

The Star…

- Close, bright object
  - Temperature
  - Luminosity
  - Surface abundances
  - Radius
- Close binary
  - Precise mass

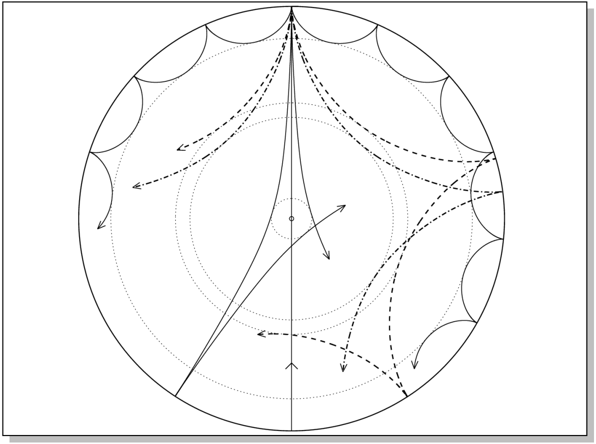
…its Heart

- Age
- Asteroseismology



Credit: ESO/Digitized Sky Survey 2

Asteroseismology

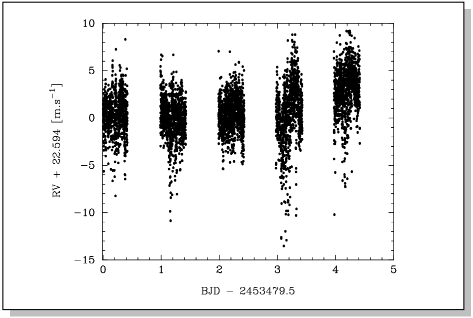


Credit: J. Christensen-Dalsgaard

Asteroseismic data

Three ground-based campaigns

- Coralie (obs. 2001)
- UVES + UCLES (obs. 2001)
- HARPS (obs. 2005)



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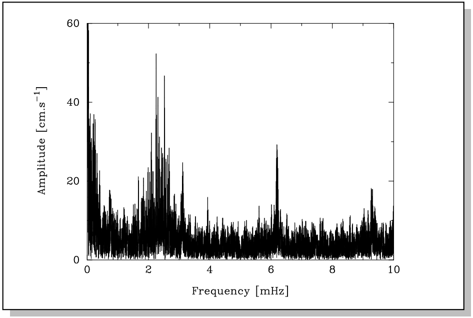

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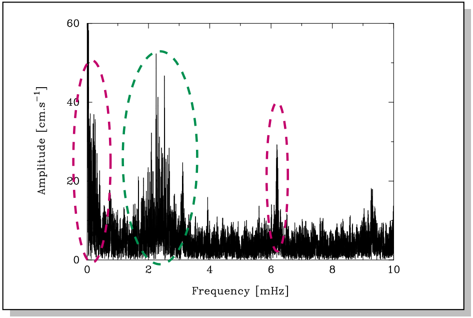

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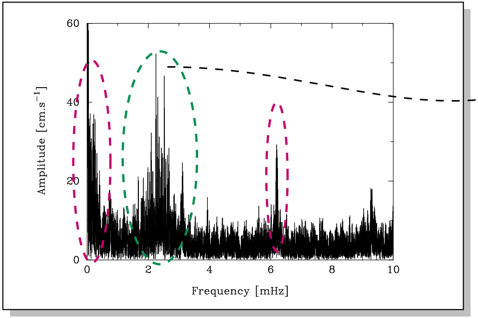
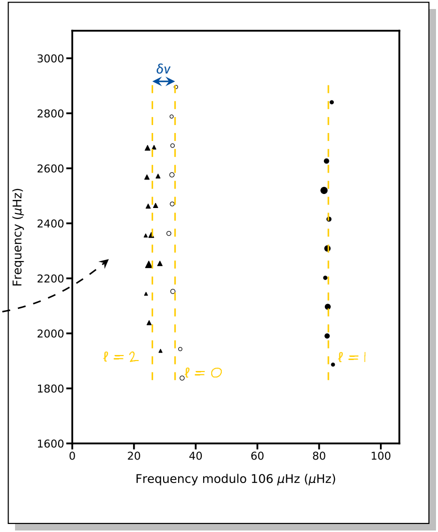




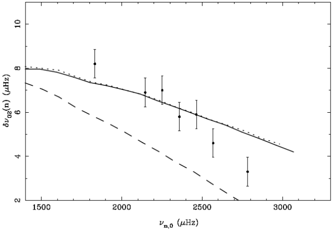
The first seismic models

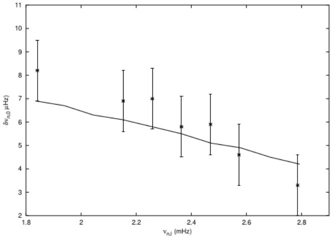
Star Core Wars

- Convective core (Thévenin et al. 2002)
- Radiative core (Thoul et al. 2003)

But why !?

- Same seismic data
- Some other data may vary
- Different codes





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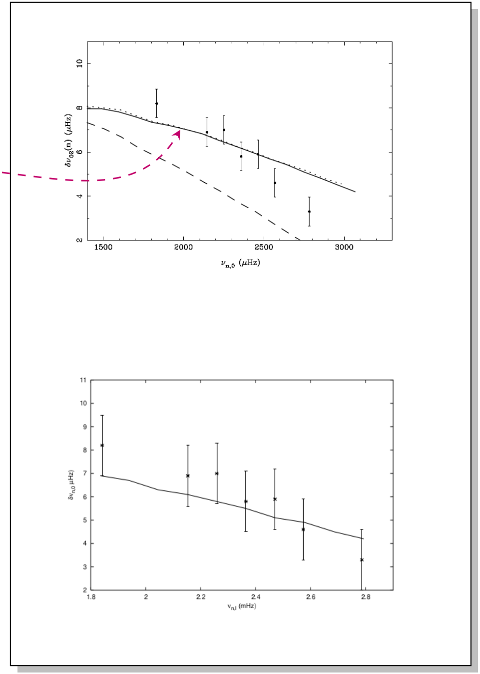

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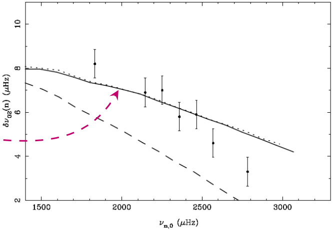
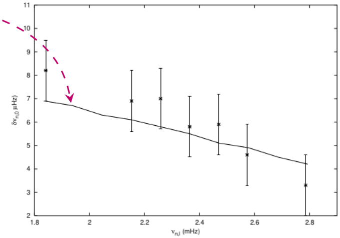
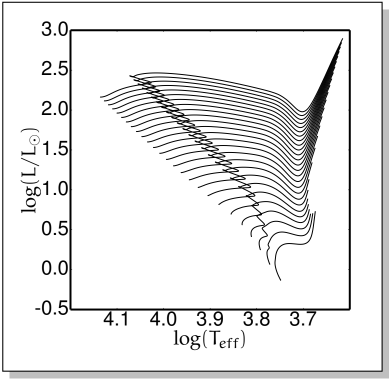


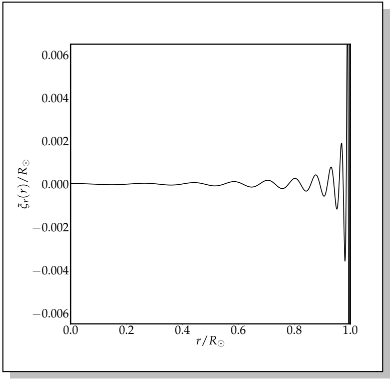


The stellar model

Structure and evolution – ASTEC

- Opal 95 opacities
- Opal equation of state
- Abundances: Grevesse et al. 1993





Oscillation – adipls

- Adiabatic
- Non-radial

Inverse problem

Parameter estimation

$$\boldsymbol{d} \rightarrow \hat{\boldsymbol{p}}$$

$$\boldsymbol{p} = \{M, \tau, X_0, Z_0, \alpha, \alpha_{ov}\}$$

Bayesian model

Statistical model (likelihood)

$$\pi(\boldsymbol{d}|\boldsymbol{p}) = L(\boldsymbol{p}|\boldsymbol{d})$$

Bayesian model
(likelihood + prior)

$$\pi(\boldsymbol{p}|\boldsymbol{d}) \propto \pi(\boldsymbol{p})L(\boldsymbol{p}|\boldsymbol{d})$$

Sampling

Markov chain Monte Carlo

Data

- Temperature 5810 ± 50 K
- Luminosity 1.522 ± 0.30 $L_\odot$
- Metallicity Z/X = 0.039 ± 0.006
- Radius 1.224 ± 0.003 $R_\odot$
- Seismic data: HARPS

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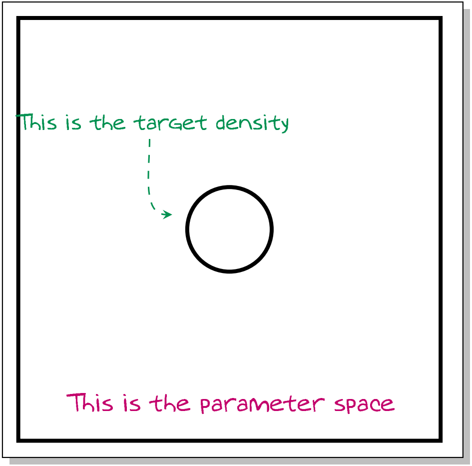

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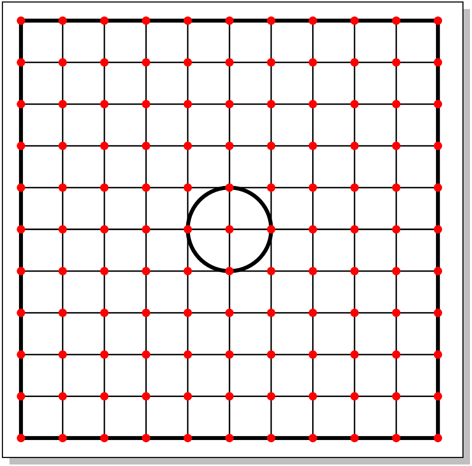

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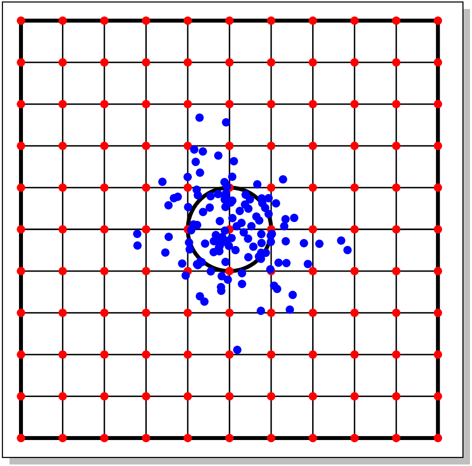
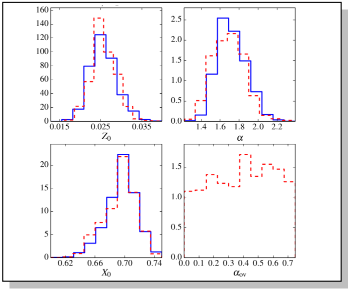
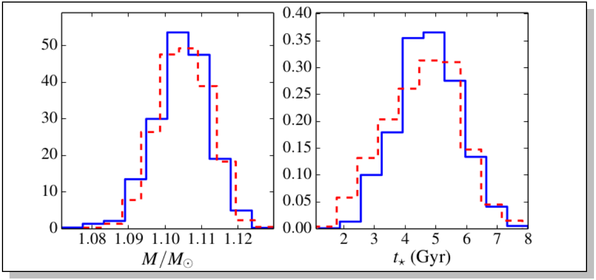


First results

Varying prescriptions

- NACRE reaction rates
- Overshoot: on/off





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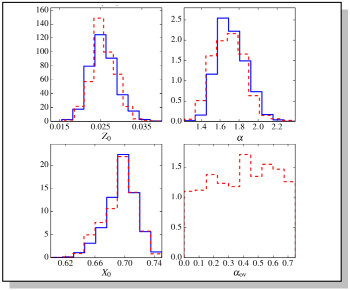
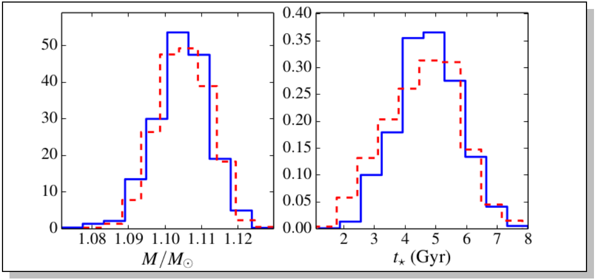


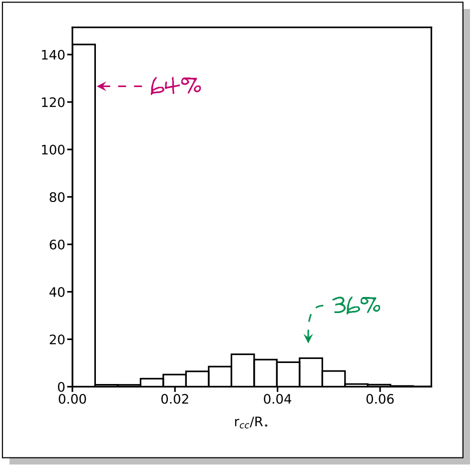
1.105 ± 0.001 $M_\odot$



Is there a convective core?

A convective core means

- Younger
- Initially more metal-rich & H poor
- Lower mixing-length parameter



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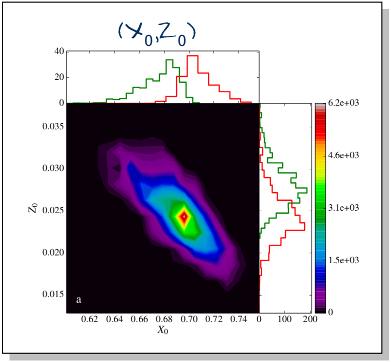

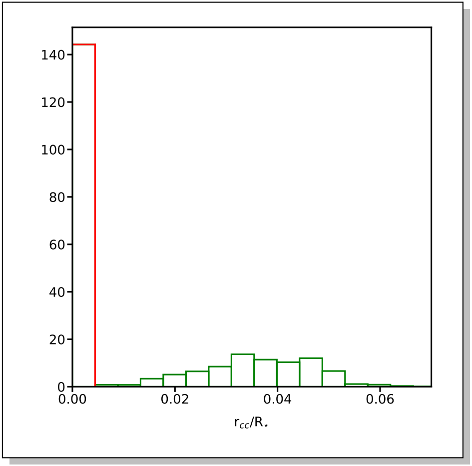

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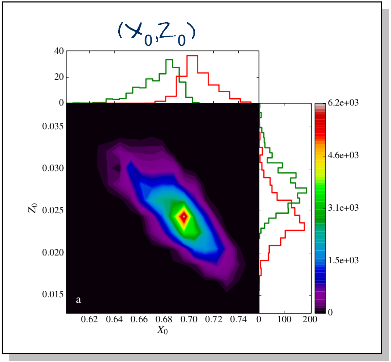
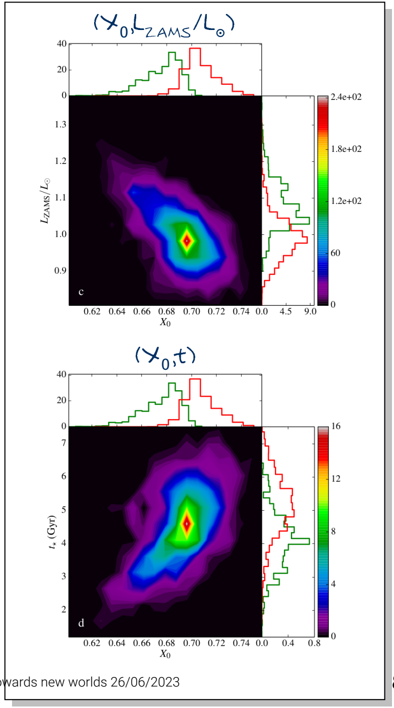
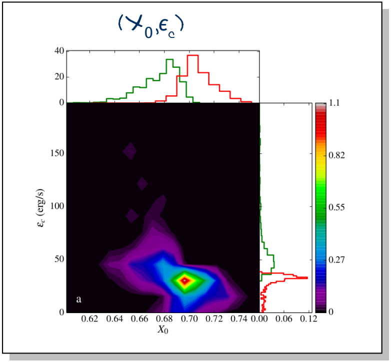


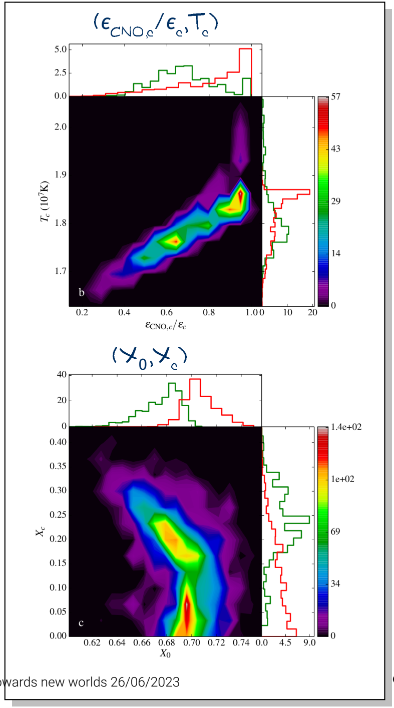


The many cores of α Cen A

Three shall be the number

- Convective core
- Radiative with H burning
- Isothermal radiative

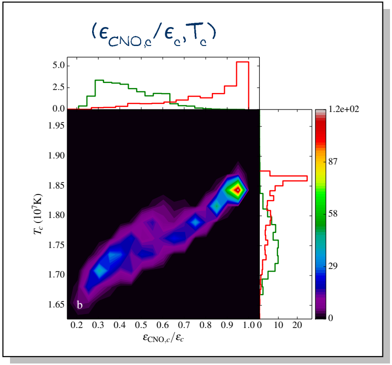


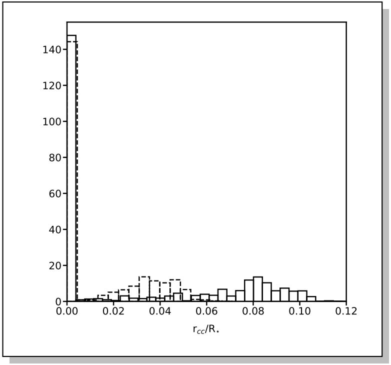


Or is that so?

Changing the rates

- LUNA rates: ~3% with convective cores
- Distinguishing rates?





"Non-standard" effects

- Overshoot: larger cores, ppII
- He diffusion: ~89% with convective cores

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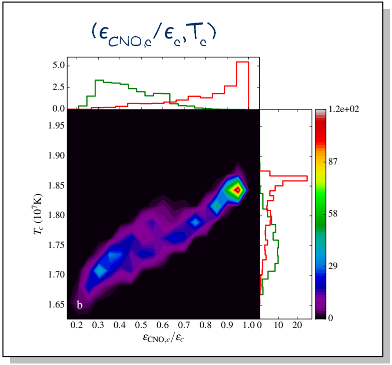

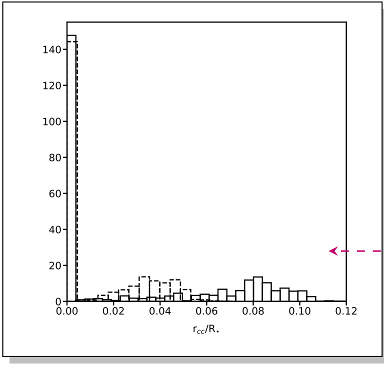

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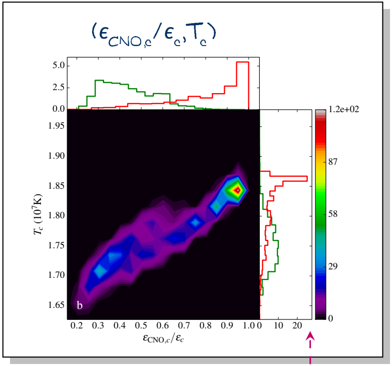

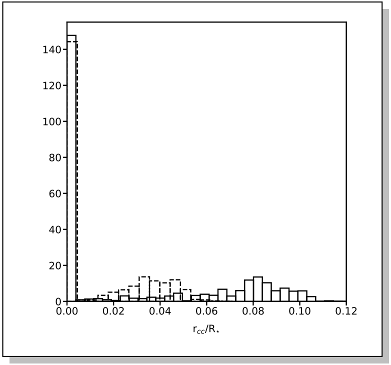

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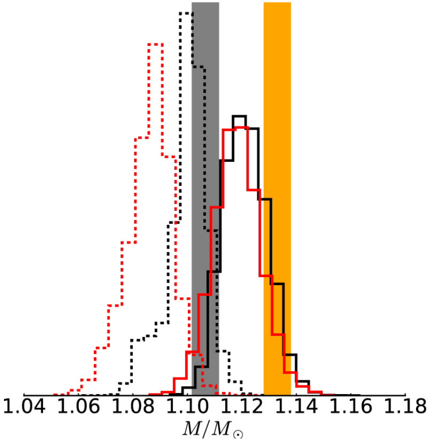
Going further

Nsamba et al. (2018)

- Data
  - de Meulenaer et al. (2010)
- Model: MESA
- Method
  - Bayesian setting
  - Sampling: AIMS

Salmon et al. (2021)

- Data
  - de Meulenaer et al. (2010)
- Model: MESA
- Method
  - Frequentist setting
  - Optimization (Levenberg-Marquardt)



NSamba et al. (2018)

Conclusions & Perspectives

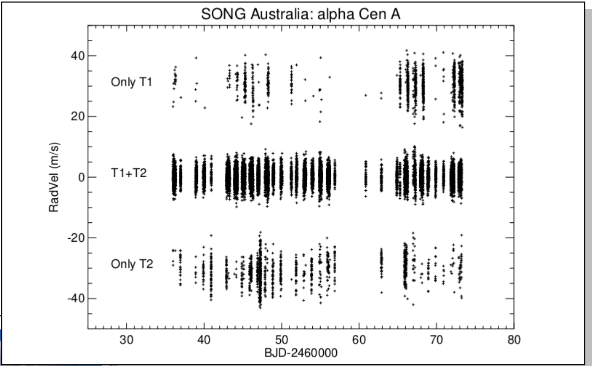
Next steps for α Cen A

- Synthesis?
  - Same data
  - Same model
  - Same method
- Benchmarking (PLATO)

Seismology – present & future

- Re-analyzing old data?
- PLATO → No
- Large telescopes → ?

SONG — The α Cen A sessions



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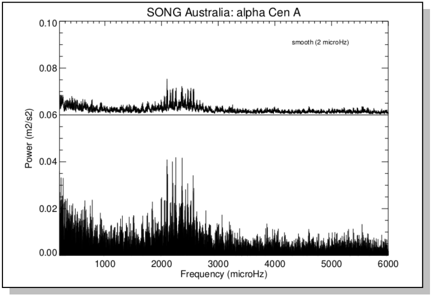

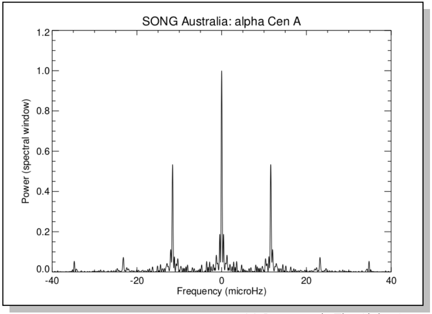

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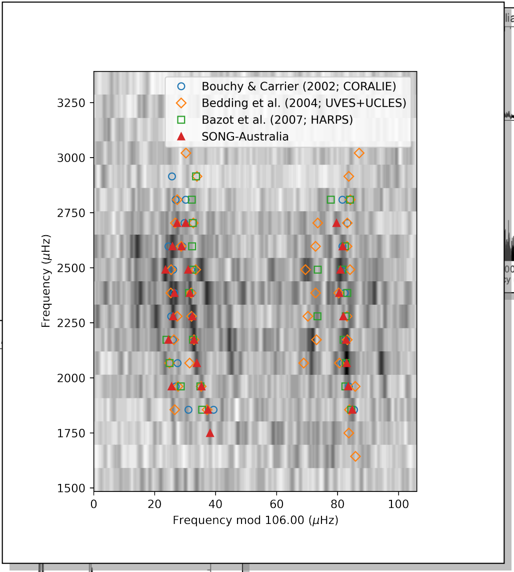

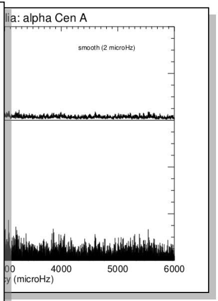

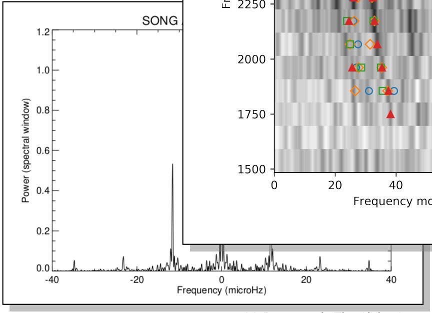

Conclusions & Perspectives

Seismology – present & future

- Rotation
- Differential rotation
- Activity
- Connecting seismology and other approaches

Next steps

- Data analysis
- Synthesis
  - Same data
  - Same model
  - Same method
- Benchmarking improved by SONG (still for PLATO)

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Back to the core !