

# (Rev)AMP: update methods for stellar parameter estimation

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<http://amp.phys.au.dk/> Metcalfe, Creevey, Christensen-Dalsgaard 2009

The screenshot shows the AMP website with a dark blue header and navigation bar. The main content area is white with a blue sidebar on the left. The sidebar contains a 'News' section with a headline '42 solar-type stars' and a 'Welcome to AMP!' section with a login form. The main content area has a 'Welcome to the XSEDE Asteroseismic Modeling Portal' section with a description of the portal's purpose and a 'What can I do with AMP?' section with two bullet points. A large image of a star's internal structure is on the right.

**AMP Asteroseismic Modeling Portal**

Find a star:

Home Find a Star Submit a Run About AMP Using AMP Login

**News**

**42 solar-type stars**

April 20, 2014, 4:20 p.m.  
Uniform AMP results for a large sample of stars are now available ...  
[Read more](#)

**Welcome to AMP!**

Please log in.

Username:

Password:

[Why login?](#) [Register](#) [Forgot password?](#)

**Recent Runs**

| Title       | Submitter  | Completed       |
|-------------|------------|-----------------|
| Newinstall3 | haiying xu | Mon 06 Oct 2014 |

**Welcome to the XSEDE Asteroseismic Modeling Portal**

The Asteroseismic Modeling Portal (AMP) provides a web-based interface for astronomers to use the [Aarhus Stellar Evolution Code](#) (ASTEC) coupled with a [parallel genetic algorithm](#) (MPIKAIA) to derive the properties of Sun-like stars from observations of their pulsation frequencies. For example, check out the data from our favorite star, [the sun](#).

**What can I do with AMP?**

Everyone can browse the catalog of runs to find data about stars that have been modeled with AMP. You can find basic properties of the stars, such as their radius, mass, and age, and you can download a Hertzsprung-Russell (HR) diagram that shows the star's temperature and luminosity during its lifetime.

Scientists can use AMP to do two things:

- **Observable parameter optimization.** In an optimization run, a scientist specifies observable properties, such as pulsation frequencies, and a genetic algorithm is used to identify the stellar model that best fits the observed data. An optimization run makes extensive usage of XSEDE computational resources and consumes about 20,000 CPU hours.
- **Direct ASTEC model evaluation.** In a direct model run, a scientist specifies a star's parameters, and a model is out the hypothetical star, including Echelle and HR diagrams, are produced for tion takes about 15 minutes to run.

ase see [About AMP](#) and the [AMP User Guide](#).



**Observatoire**  
de la CÔTE d'AZUR

# Observables - Parameters

## INPUT

- Frequencies
- Atmospheric params
- Diameters
- Distance

## OUTPUT

- Mass
- Radius
- Age
- Luminosity...
- + uncertainties/correl

# Method

- GA combination of encoded params: 126 x (Y<sub>i</sub>Z<sub>i</sub>Mα)
- Evolution track + oscillations, optimization Dn, n0
- Comparison of freq ratios\* by 'Chi2' (using cov mat)

$$\chi^2 = (x - x_M)^T C^{-1} (x - x_M)$$

- Comparison of other input params 'Chi2'
- Save output and 'fitness'
- GA recombination by 'mutations' and 'evolution' to determine next 126 combinations (200 gen. Total)

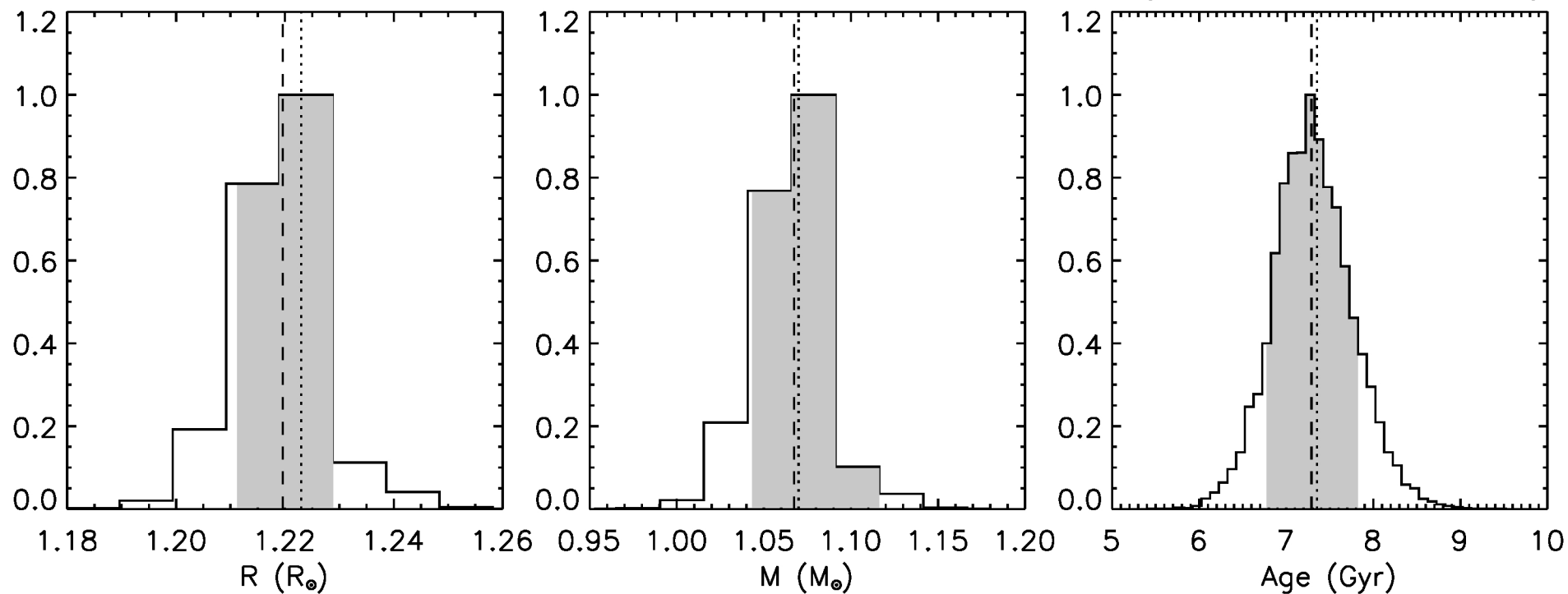
\* or individual frequencies, or mix of both

# Post-processing

- GA Optimal model from 4 independent runs
  - Frequencies, ratios, radius, ...
- Full evolution of GA recorded
- Uncertainties by two methods:
  - Chi2 limit
  - Likelihood
- Mean parameters  $\langle \mathbf{P} \rangle$ ,  $\sigma$  and (mod'd) optimal model  $\mathbf{P}_{OPT}$
- Use as final results or starting point for refinement or exploration of other physics

# Likelihood

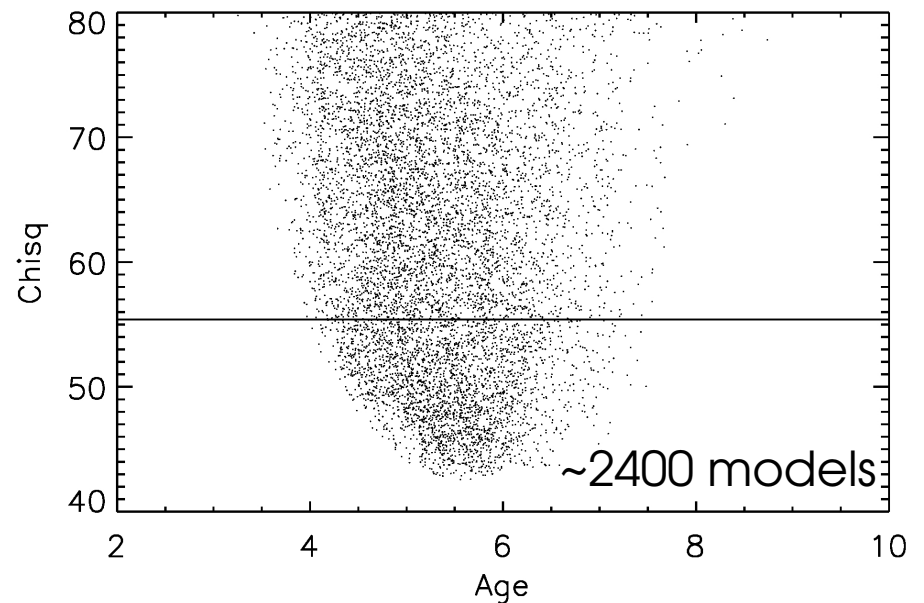
Creevey, Metcalfe, et al. In prep



$$\mathcal{L} = \mathcal{L}_{\text{seis}} \cdot \mathcal{L}_{\text{T}_{\text{eff}}} \cdot \mathcal{L}_{[\text{M}/\text{H}]}$$

# Chi2 limit

- Filter by complementary constraints (2sigma, for ex)
- Determine degrees of freedom
- Calculate confidence interval limit for 95%
- Determine range of parameters, e.g. Rmin Rmax, for all models within criteria
- If one model way out, ignored, otherwise use  $(\max - \min)/4$  as sigma.



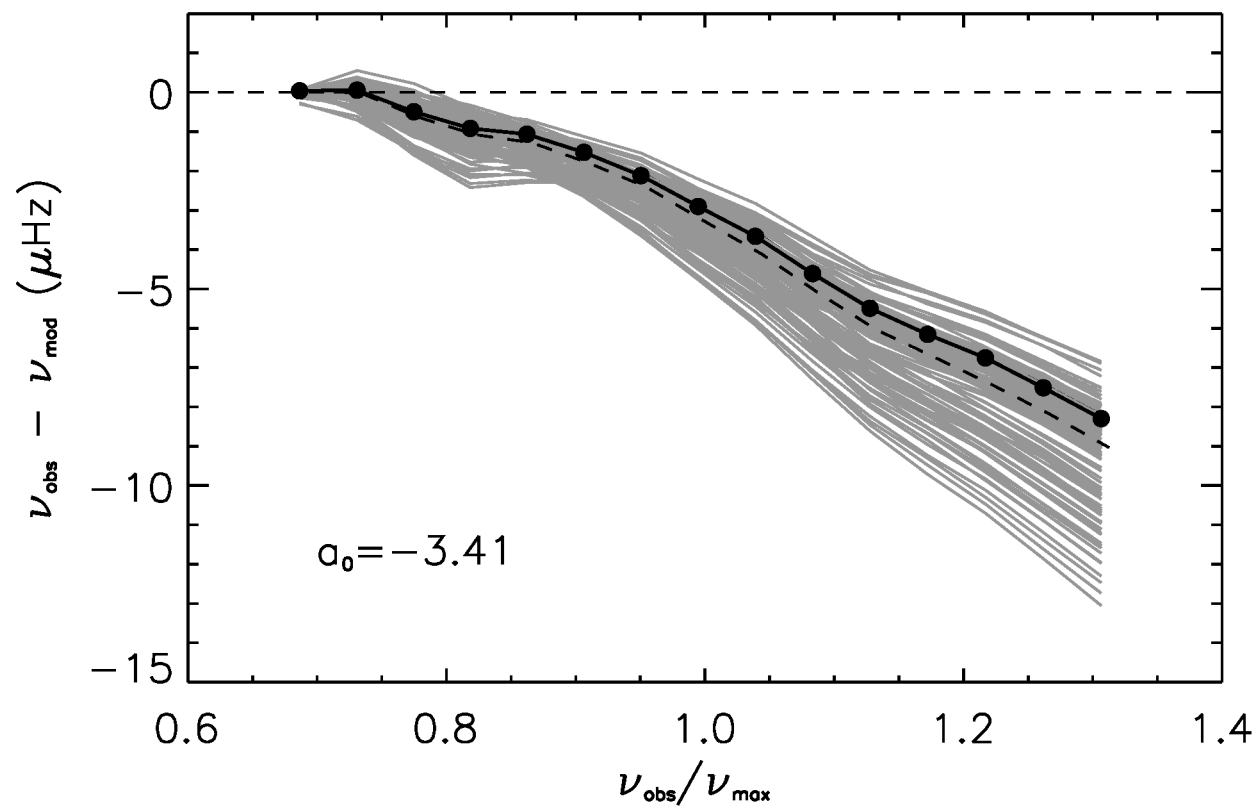
# Sun

Creevey, Metcalfe, et al. In prep

|                       | AMP <sub>1</sub> | AMP <sub>2</sub> | AMP <sub>3</sub> | AMP <sub>4</sub> | $\langle P \rangle$ | $\sigma$ |
|-----------------------|------------------|------------------|------------------|------------------|---------------------|----------|
| $R$ (R <sub>⊙</sub> ) | 1.002            | 1.003            | 1.003            | 1.010            | 1.001               | 0.009    |
| $M$ (M <sub>⊙</sub> ) | 1.01             | 1.01             | 1.01             | 1.03             | 0.995               | 0.031    |
| Age (Gyr)             | 4.59             | 4.38             | 4.41             | 4.69             | 4.54                | 0.28     |
| $Z_i$                 | 0.019            | 0.021            | 0.020            | 0.024            | 0.017               | 0.002    |
| $Y_i$                 | 0.266            | 0.281            | 0.278            | 0.282            | 0.265               | 0.023    |
| $\alpha$              | 2.16             | 2.24             | 2.24             | 2.30             | 2.12                | 0.12     |
| $L$ (L <sub>⊙</sub> ) | 0.96             | 0.99             | 0.99             | 1.00             | 1.00                | 0.04     |
| log $g$ (dex)         | 4.441            | 4.439            | 4.439            | 4.442            | 4.439               | 0.004    |
| $\chi^2$              | 1.047            | 0.968            | 0.995            | 1.058            |                     |          |

# Sun

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# Advantages

- Automatic, requires input ascii file (freq + ..)
- Full exploration of parameter space for 1 set of physics
- Simple implementation of core ovrsh and diffusion (1/0)
- “Fast” =
  - local implementation 24-36hours MS (4x20cpu, but 4 stars simult!)
  - AMP < 1 day MS/sG (4x127cpu)
- Currently configured with AMP, to be configured with MESA
- GA evolution logged

# Disadvantages

- Require matching lowest frequency to  $\sim 1\text{-}2 \mu\text{Hz}$  (H&H2)
- Changing more physics, more difficult but mesa
- “black-box” ish, but algorithm easy to modify (F77)
- “Long” so important to monitor runs (but robotic with shell scripts)
- High and Low  $Y_i$  initial chemical composition (no Z diff)

# Next steps

- Rerun H&H again
- MESA implementation
- Tests on fixing of base frequency
- Tests on limiting  $Y_i$
- Uncertainties -> f77 (currently offline IDL)

Thank you!

