New PARSEC database
of α-enhanced stellar tracks and isochrones

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Sep. 08, 2017 @ Catania

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PARSEC stellar model

Why $\alpha$ enhancement?

Calibration with 47Tuc

Improvement on RGBB
PARSEC (PAdova-TRieste Stellar Evolution Code)
PARSEC (PAdova-TRieste Stellar Evolution Code)

- Population synthesis (e.g. Bruzual & Charlot, 2003)
- Chemical evolution of galaxies (e.g. Ryde et al., 2015; Vincenzo et al., 2016)
- To Derive black hole masses when observing gravitational waves (e.g. Spera, Mapelli & Bressan, 2015; Belczynski et al., 2016)
- To get host star parameters for exoplanets (e.g. Santos et al., 2013)
- To study star clusters (e.g. Donati et al., 2014; Borissova et al., 2014; San Roman et al., 2015)
- To study Galactic structure (e.g. Kupper et al., 2015; Li et al., 2016; Balbinot et al., 2016)
- To study dust formation (e.g. Nanni et al., 2013; Nanni et al., 2014)
- To constrain dust extinction (e.g. Schlafly et al., 2014; Schultheis et al., 2015; Bovy et al., 2016)
- To understand the stars themselves (e.g. Kalari et al., 2014; Smiljanic et al., 2016; Gullikson, Kraus et al 2016; Reddy & Lambert, 2016; Casey et al., 2016)
- .etc.
**CMD 3.0 input form**

A web interface dealing with stellar isochrones and their derivatives

NEW! (05may17) List of filters cleaned
(18apr17) Several bugs corrected, so the probability of creating empty files is much reduced.

Help desk: 
Submit | Reset

**Evolutionary tracks**

TP-AGB tracks from COLIBRI are now available.

[Image of a webpage with a link to the PAdova-TRieste Stellar Evolution Code]
Solar-scaled mixture

initial partition of heavy elements
keeps always the same relative
number density as that in the Sun.

\[ [X/Fe] = \log \frac{n(X)}{n(Fe)} - \log \frac{n(X)_\odot}{n(Fe)_\odot} = 0 \]
Solar-scaled mixture

initial partition of heavy elements keeps always the same relative number density as that in the Sun.

\[
[X/Fe] = \log \frac{n(X)}{n(Fe)} - \log \frac{n(X)}{n(Fe)_\odot} = 0
\]

α elements \[\alpha/Fe] > 0

Globular Clusters, Galactic bulge/thick disk/halo
α elements  \([\alpha/Fe] > 0\)

Globular Clusters, Galactic bulge/thick disk/halo

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Venn et al. (2004):
- Milky Way halo
- Milky Way thick disk
- Milky Way thin disk

Kirby et al. 2009
\( \frac{\alpha}{Fe} > 0 \)

**Globular Clusters, Galactic bulge/thick disk/halo**

- Massive stars (fast) Core collapse SNe
  - mainly produce \( \alpha \)-elements
    - (O, Ne, Mg, Si, S, Ar, Ca, and Ti)

- Binaries (After WD) Type Ia SNe
  - iron-peak elements
    - (V, Cr, Mn, Fe, Co and Ni)

Kirby et al. 2009
[α/Fe] profiles

Record SFH
(See Kordopatis’ talk)

α elements $[\alpha/Fe] > 0$

Globular Clusters,
Galactic bulge/thick disk/halo

• Massive stars $\xrightarrow{\text{fast}}$ Core collapse SNe
  mainly produce $\alpha$-elements
  (O, Ne, Mg, Si, S, Ar, Ca, and Ti)

• Binaries $\xrightarrow{\text{After WD}}$ Type Ia SNe
  iron-peak elements
  (V, Cr, Mn, Fe, Co and Ni)
Effect of $\alpha$ enhancement on stellar evolution

\[ Z=0.0055 \quad Y=0.276 \quad M=0.85M_\odot \]

- Solar scaled
- $\alpha$ enhanced

$\log(L/L_\odot)$ vs. $T_{\text{eff}}$ (K) and $\log(L/L_\odot)$ vs. age (Gyr)
Calibrate $\alpha$-enhanced models with 47Tuc (NGC 104)

<table>
<thead>
<tr>
<th></th>
<th>FG</th>
<th>SG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>0.0056</td>
<td>0.0055</td>
</tr>
<tr>
<td>Y</td>
<td>0.256</td>
<td>0.276</td>
</tr>
<tr>
<td>[M/H]</td>
<td>-0.43</td>
<td>-0.41</td>
</tr>
<tr>
<td>[Fe/H]</td>
<td>-0.76</td>
<td>-0.76</td>
</tr>
<tr>
<td>[$\alpha$/Fe]</td>
<td>$\sim$0.4</td>
<td>$\sim$0.2</td>
</tr>
</tbody>
</table>
Isochrone fitting

\[ \Lambda_e = 0.5 \]

Data: ACS survey of GCs

- PARSEC with ATLAS12+Phoenix:
  - \( Z = 0.0056 \), \( Y = 0.256 \)
  - \( Z = 0.0055 \), \( Y = 0.276 \)

Age = 12.00 Gyr

\( (m-M)_0 = 13.22 \)

\( (4.406 \text{ Kpc}) \)

\( E(V-I) = 0.035 \)
Isochrone fitting

age = 12 Gyr

$(m-M)_0 = 13.22$

$(4.406 \text{ Kpc})$

$E(V-I) = 0.035$
Second parameter problem in GC

Age, He, mass loss, density…
HB morphology and LF

\[ \eta = 0.20 \]

\[ \eta = 0.25 \]

\[ \eta = 0.30 \]

\[ \eta = 0.35 \]

\[ \eta = 0.40 \]

\[ Z = 0.0056 \quad Y = 0.256 \]

\[ Z = 0.0055 \quad Y = 0.276 \]

\[ Z = 0.0056 \quad Y = 0.276 \]

\[ Z = 0.0055 \quad Y = 0.296 \]

Age = 12.00 Gyr
DM = 13.22
E(V−I) = 0.035
HB morphology and LF

Most favourable factor for 47Tuc $\eta=0.35$

\[ \sim 0.17 \text{M}_\odot \]
HB morphology and LF

FG: 30%
SG: 70%

Milone et al. 2012
Carretta et al. 2009
RGB bump and envelope overshooting calibration

NGC 104 (47 Tuc) 
[Fe/H] = -0.76

Surface convective zone

H-burning shell

Z = 0.0055 Y = 0.276 M = 0.85M\odot
RGB bump and envelope overshooting calibration

\[ \log \left( \frac{L}{L_\odot} \right) \]

\[ Z = 0.0055 \quad Y = 0.276 \quad M = 0.85M_\odot \]

Surface convective zone

H-burning shell
RGB bump and envelope overshooting calibration

Sensitive to:
- Total metallicity.
- Metal partition.
- Helium content.
- Age.
- Mixing efficiency
Envelope overshooting

Solar example
Envelope overshooting

\[ \Lambda_e = 0.05 \quad \Delta t_{\text{RGB}} = 20.440 \text{Myr} \]
\[ \Lambda_e = 0.3 \quad \Delta t_{\text{RGB}} = 24.225 \text{Myr} \]
\[ \Lambda_e = 0.4 \quad \Delta t_{\text{RGB}} = 26.026 \text{Myr} \]
\[ \Lambda_e = 0.5 \quad \Delta t_{\text{RGB}} = 27.159 \text{Myr} \]

\[ Z = 0.0055 \quad Y = 0.276 \]
\[ M = 0.85 M_\odot \]
RGB bump and envelope overshooting calibration

$$\text{Age} = 12.00 \text{Gyr} \quad (m-M)_0 = 13.22 \quad E(V-I) = 0.035$$

- FG: 30%
- SG: 70%

Milone et al. 2012
Carretta et al. 2009

$$\Lambda_e = 0.5 H_p$$
Long-lasting RGB bump problem

$[\text{M/H}] \approx [\text{Fe/H}] + 0.33$

$\Delta V_{\text{MSTO}}^{\text{RGBB}} = M_{V,\text{MSTO}} - M_{V,\text{RGBB}}$
Comparison with GC observation

\[ [\text{M/H}] \approx [\text{Fe/H}] + 0.33 \]

\[ \Delta V^\text{MSTO}_{\text{RGBB}} = M_{V,\text{MSTO}} - M_{V,\text{RGBB}} \]
Comparison with GC observation

\[
[M/H] \approx [\text{Fe/H}] + 0.33
\]

\[
M_{V,RGBB} = m_{V,RGBB} - (m - M)_v
\]
Comparison with other models

- PARSEC $[\alpha/\text{Fe}] \sim 0.4$
- BaSTI $[\alpha/\text{Fe}]=0.4$
- DSEP $[\alpha/\text{Fe}]=0.4$
Comparison with other models
Will be online soon...

With different photometry systems
Summary

PARSEC $\alpha$-enhanced tracks and isochrones are calibrated with 47Tuc

Age, distance, extinction, and RGB mass loss of 47Tuc are derived with isochrone global fitting

New models close the gap between RGBB observation and prediction
Comparison with other models
RGB with different atmosphere models

With PHOENIX

With ATLAS12+PHOENIX