# Challenge: Test 2 – Unresolved Stellar Populations

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We analyzed the spectra of five stellar clusters using SSPs models built with different codes and ingredients (stellar libraries and tracks). We performed the analysis by using the code STARLIGHT, which decomposes an observed spectrum in terms of a superposition of a base of simple stellar populations of various ages and metallicities, producing as output the star-formation history (SFH) of a galaxy, its extinction and velocity dispersion. The code and its details are described in http://www.astro.ufsc.br/~jean/Challenge/.

Our aim for this test was to find the best model fit for each cluster spectrum, but we warn the reader that more precise results would require additional fine tuning and toying with the code and the model bases. Most importantly, we wanted to illustrate how the results compare among themselves when different ingredients are employed.

We tested SSPs models generated with:

- two stellar population synthesis codes: GALAXEV by Bruzual & Charlot (2003; BC03) and Starburst99 (Leitherer et al. 1999; SB99);
- three stellar libraries: STELIB (which is the empirical library used on BC03 models), Martins et al. (2004) theoretical library (used with Starburst99 code) and Coelho et al. (2005) theoretical library (used with GALAXEV code);
- two sets of isochrones: Girardi et al. (2000; Padova 2000) and Bertelli et al. (1994; Padova 1994), and;
- two IMFs: Salpeter (1955) and Chabrier (2003).

Not all possible ingredient combinations were produced, but we believe that the combinations presented here are already enough for what has been proposed. The models cover in general ages from 3Myr to 15 Gyr, and [Fe/H] from -0.7 to 0.2. Exceptions are the models based on Coelho library, which cover only ages older than 3Gyr and [Fe/H] above -0.5. The values for [alpha/Fe] could be derived when Coelho et al. library was employed, but we stress that the isochrones considered (Padova 1994 and 2000) are valid for solar-scaled abundance patterns, and thus may not be suitable for producing alpha-enhanced SSP models. Nevertheless, we choose not to compute models with the alpha-enhanced set of isochrones by the Padova group (Salasnich et al. 2000) due to the recent results by Weiss et al. (2006).

It is important to note that the age and metallicity spacing of the models is not fine enough to allow exact determinations. Therefore, the code may find that the best solution is a combination of SSPs even for stellar cluster spectra, to compensate for the lack of fine steps in the parameter space. This is just a numerical artifact, and with that in mind we think that the results are quite satisfactory.

The results – age (in Gyr), metallicity [Fe/H] and [alpha/Fe] – found for each set of models are given in the Table below:

| **Code/IMF/ Isochrones/ Stellar library** | BC03 Salpeter Padova 2000 STELIB | | BC03 Chabrier Padova 1994 STELIB | | GALAXEV Salpeter Padova 2000 Coelho et al. | | | GALAXEV Chabrier Padova 2000 Coelho et al. | | | GALAXEV Chabrier Padova 1994 Coelho et al. | | | SB99 Salpeter Padova 1994 Martins et al. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Age | [Fe/H] | Age | [Fe/H] | Age | [Fe/H] | [alpha/Fe] | Age | [Fe/H] | [alpha/Fe] | Age | [Fe/H] | [alpha/Fe] | Age | [Fe/H] |
| **47 Tuc** | 7 | -0.1 | 6 | -0.3 | 7 | -0.3 | 0.0 | 5 | -0.2 | 0.0 | 6 | -0.5 | 0.0 | 4 | -0.3 |
| **M67** | 7 | -0.1 | 5 | 0.0 | 5 | -0.2 | 0.0 | 8 | -0.3 | 0.0 | 4 | 0.0 | 0.0 | 3 | 0.0 |
| **NGC1805** | 0.1 | 0.0 | 0.1 | 0.0 | Too young for Coelho library | | | Too young for Coelho library | | | Too young for Coelho library | | | 0.09 | 0.1 |
| **NGC1868** | 0.6 | 0.0 | 0.4 | 0.2 | Too young for Coelho library | | | Too young for Coelho library | | | Too young for Coelho library | | | 0.6 | 0.0 |
| **NGC6528** | 9.5 | 0.0 | 10 | 0.0 | 8 | -0.2 | 0.1 | 8 | -0.3 | 0.2 | 8 | -0.1 | 0.1 | 7 | -0.1 |

Some comments:

**47Tuc**

All sets of models derive a too low age for this cluster, while overestimating the metallicity: an interesting example of the age/metallicity degeneracy. The age is believed to be typical of that of the halo ~ 12 Gyrs and [Fe/H] of the order of -0.7 (Alves-Brito et al. 2005, A&A 435, 657). Alpha-enhancement may be an issue, and models with Coelho models do not recover the non-solar [alpha/Fe].

**M67**

Ages derived range from 4 to 8 Gyr (VandenBerg & Stetson 2004, PASP 116, 997 gives an age ~ 4.5 Gyr). The metallicity tends to be close to solar, in agreement with values from the literature ([Fe/H] between -0.05 and 0.03 dex and age; Randich et al. 2006, A&A 450, 557). Models with Coelho et al. library show some difficulty to model the bluest part of the spectra.

**NGC1805** and **NGC1868**

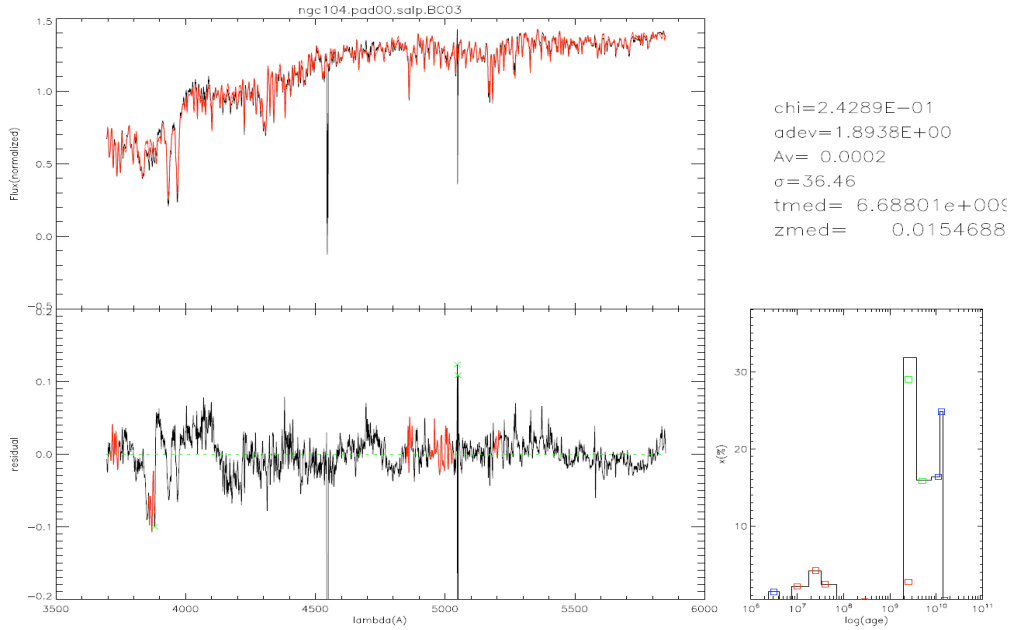
The ages of these young clusters are well reproduced by the models. Literature values are 0.02 Gyr and 0.7 Gyr respectively for NGC1805 and NGC1868 (1980 ApJ 235, 769; 2001, A&A 369, 74; 2002, MNRAS 336, 139; 1988, ASPC. 1, 197). In contrast, the models find solar metallicity which is in disagreement with the literature. The bluer part is badly fitted by all models.

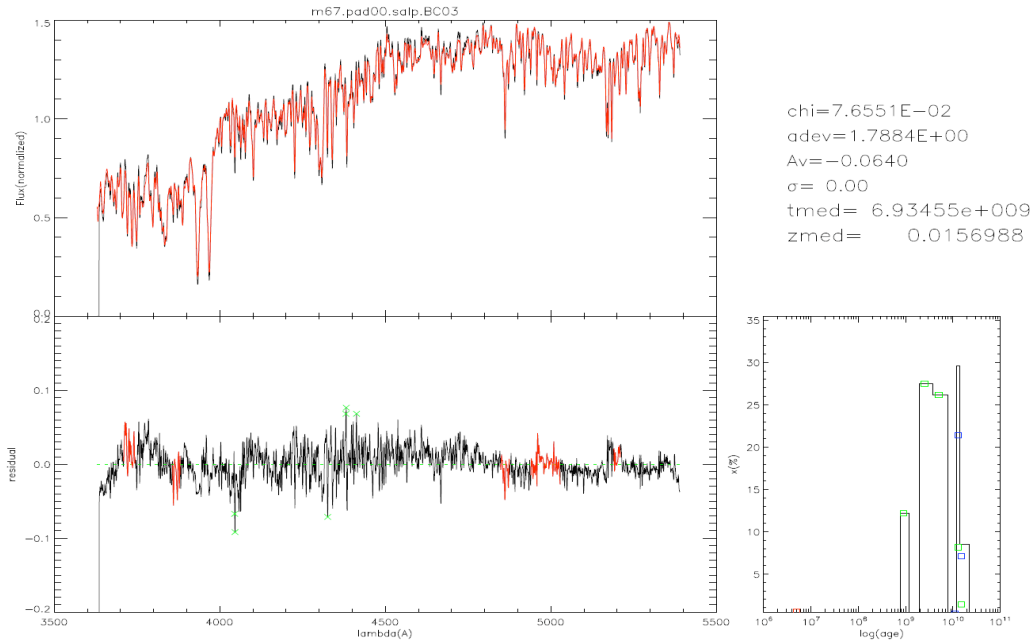
**NGC6528**

Metallicity values obtained by the models are in reasonable agreement with the literature (Zoccali et al. 2004, A&A 423, 507), but the ages tend to be systematically lower than the 11 Gyr expected (Ortolani et al. 1995, Nature 377, 701). This is a cluster where alpha enhancement is certainly important: clear signs are seen in the spectral fits, and models with Coelho library sucessfully recover an overall [alpha/Fe] which is in agreement with spectroscopic studies.

We noted that in general the models SB99 give systematically lower ages, but no clear trend was found regarding the derived metallicities. There are also no important differences between the results obtained from models based on theoretical libraries (Martins and Coelho) or empirical libraries (STELIB).

**BC03 - Salpeter - Padova 2000 – STELIB**

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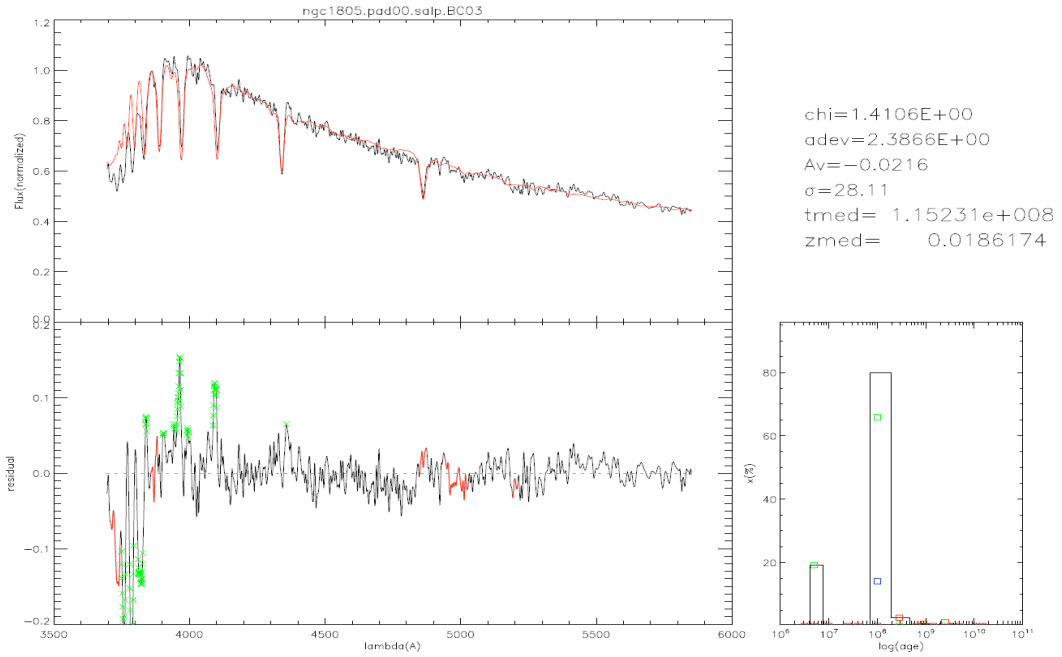


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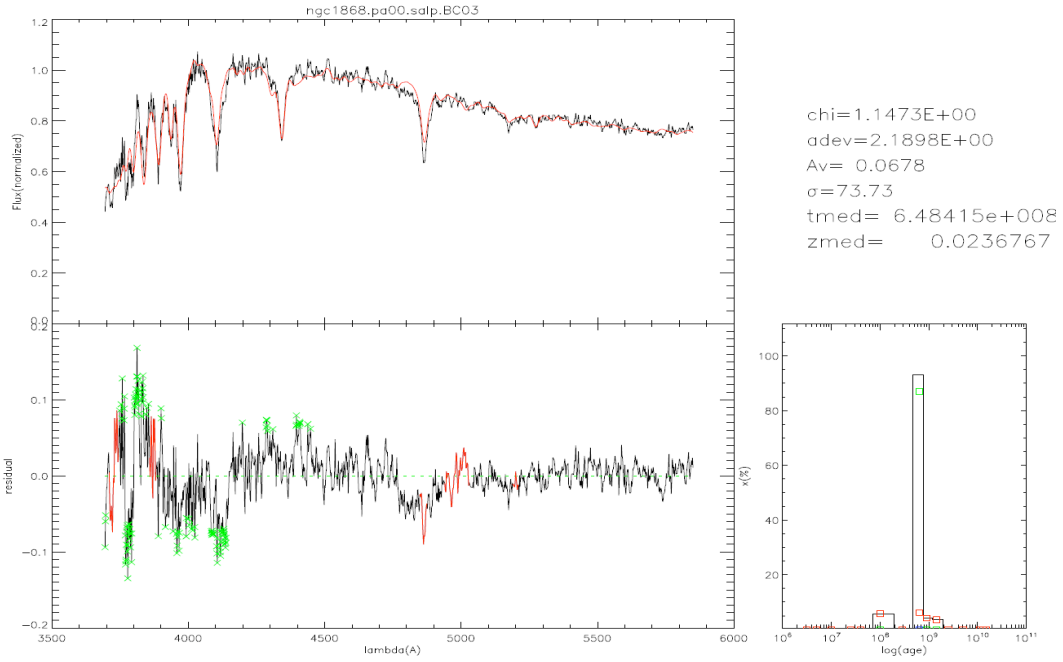


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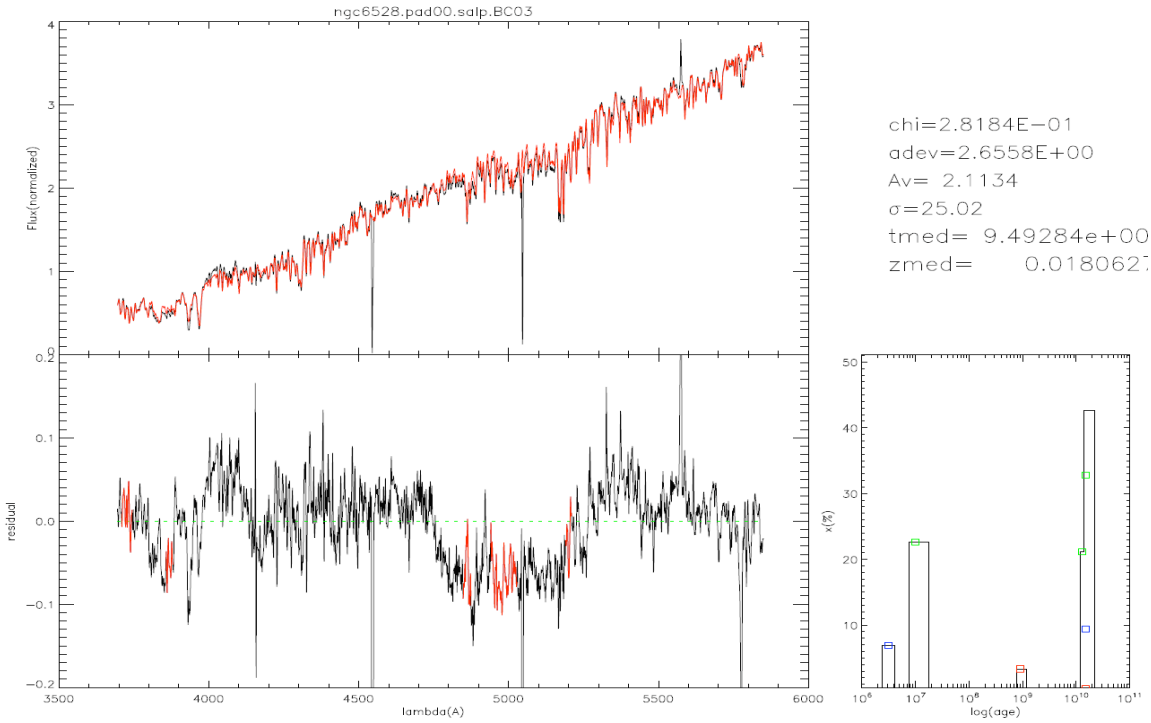


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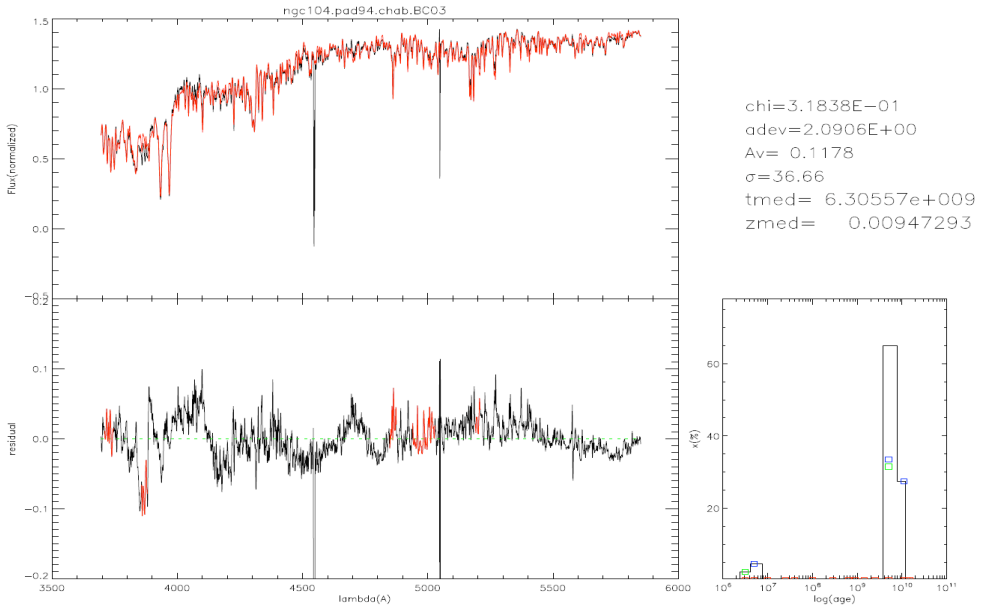
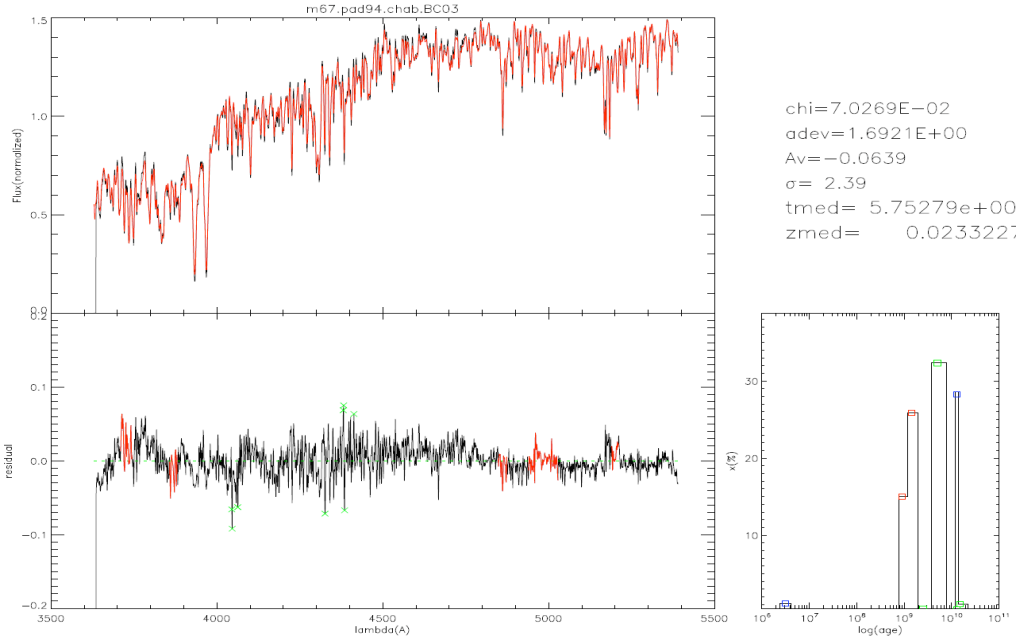
**BC03 - Chabrier - Padova 1994 - STELIB**

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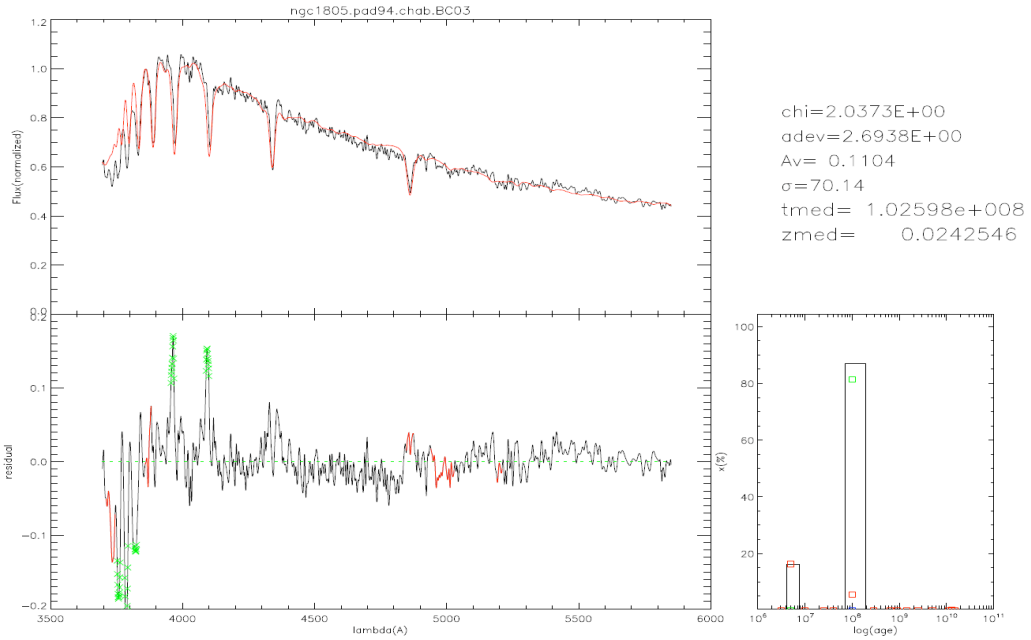


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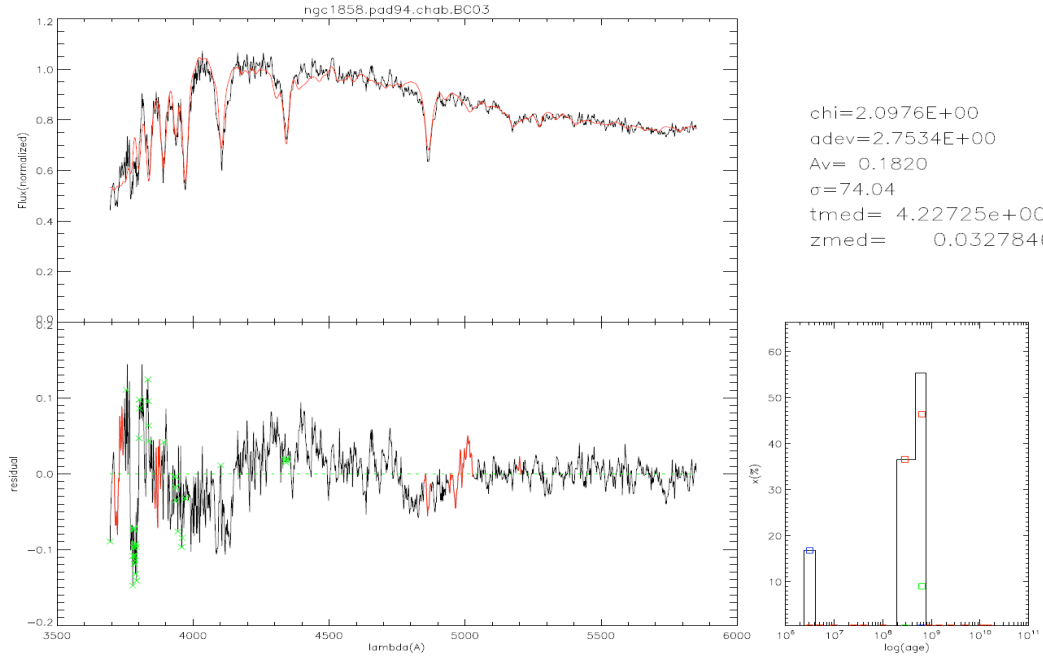


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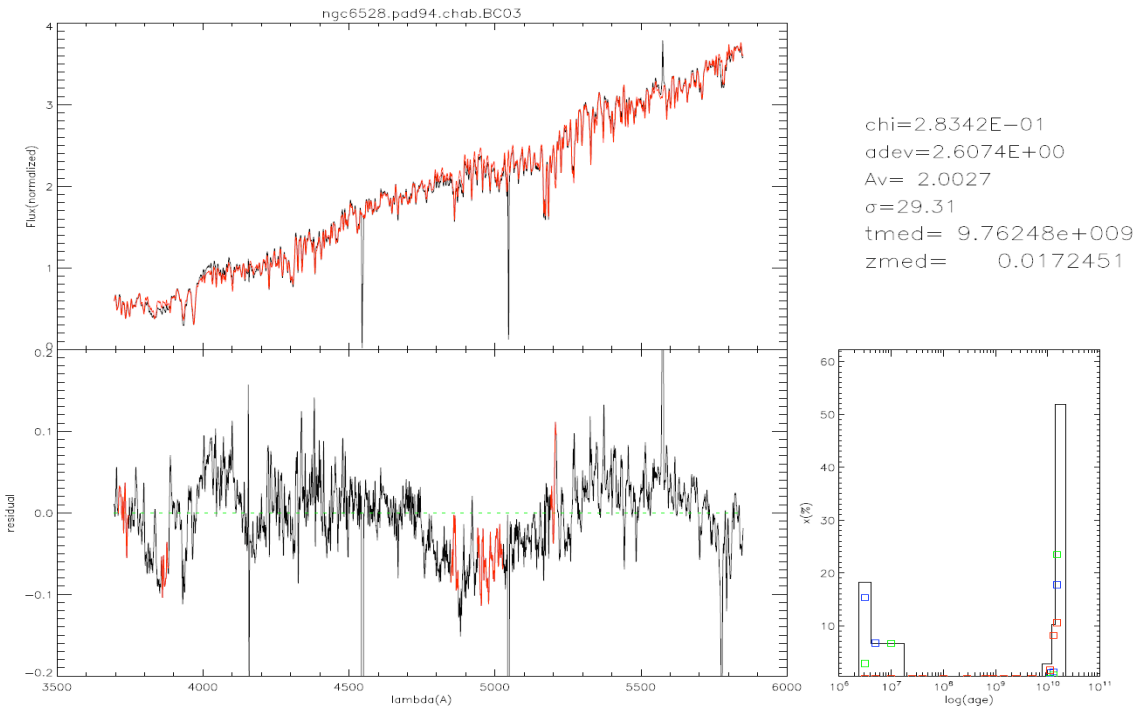


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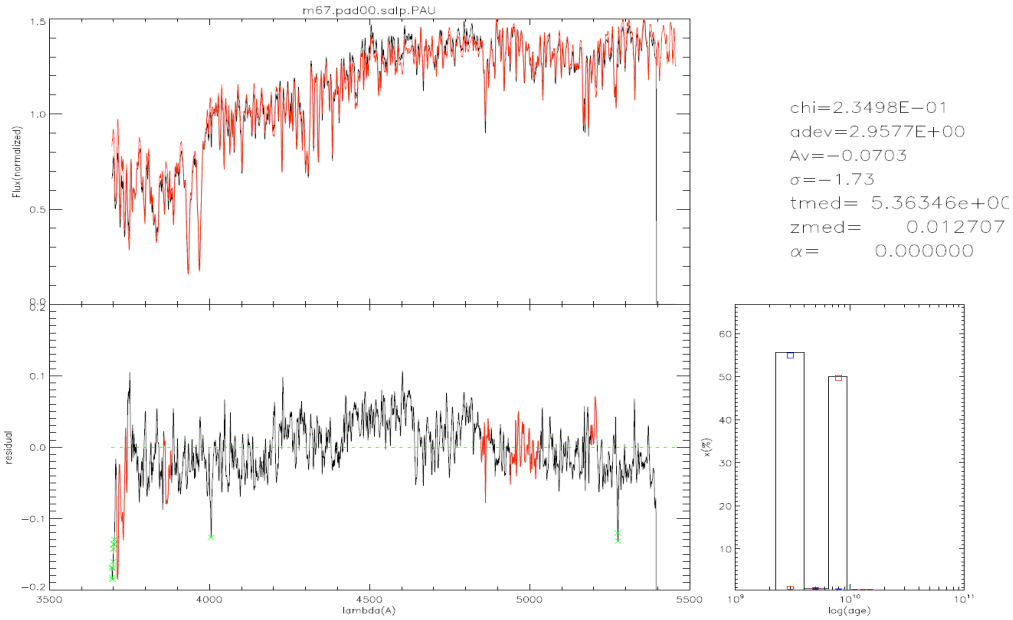
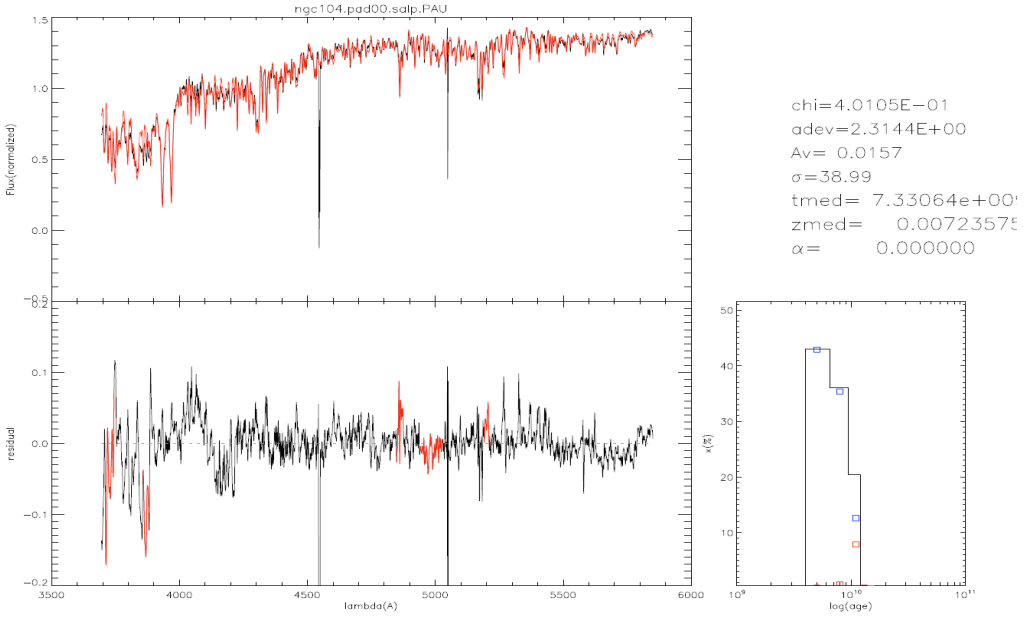
**GALAXEV - Salpeter - Padova 2000 - Coelho et al.**

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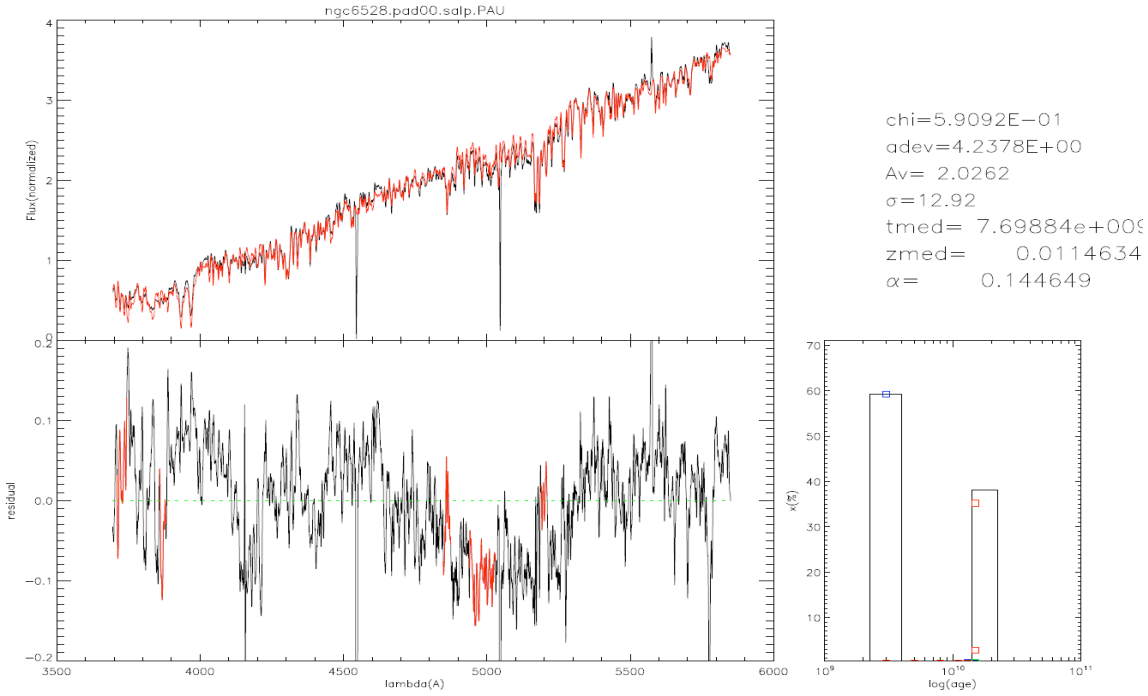


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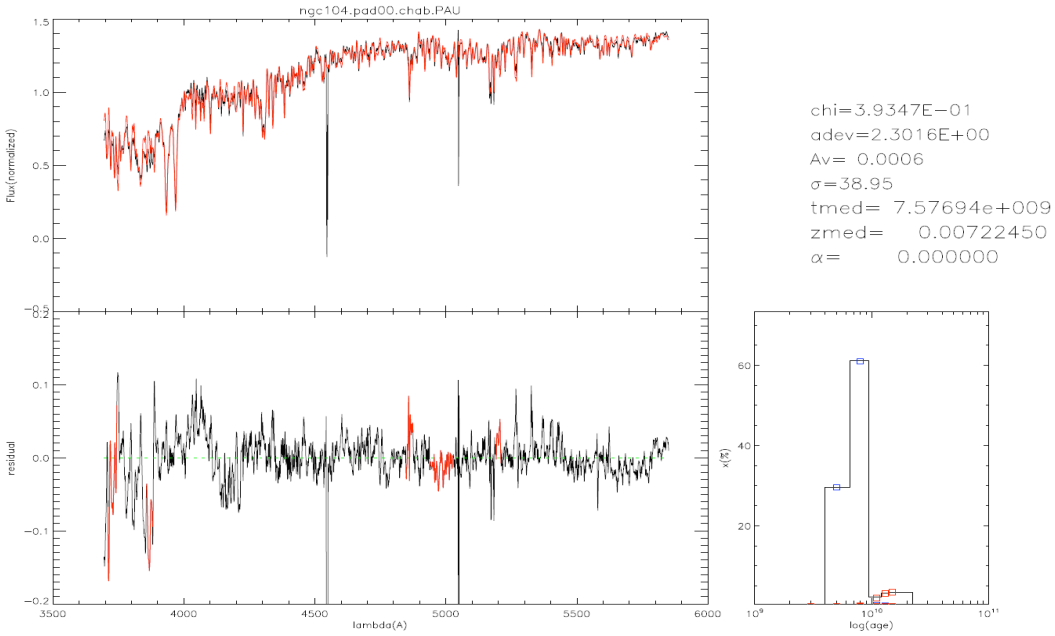
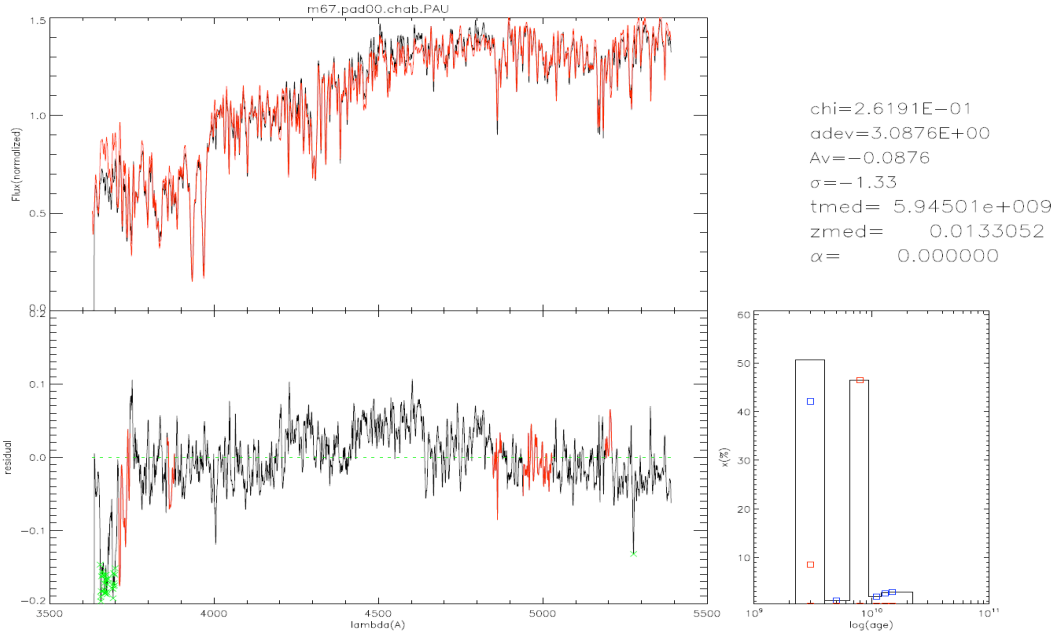
GALAXEV - **Chabrier - Padova 2000 - Coelho et al.**

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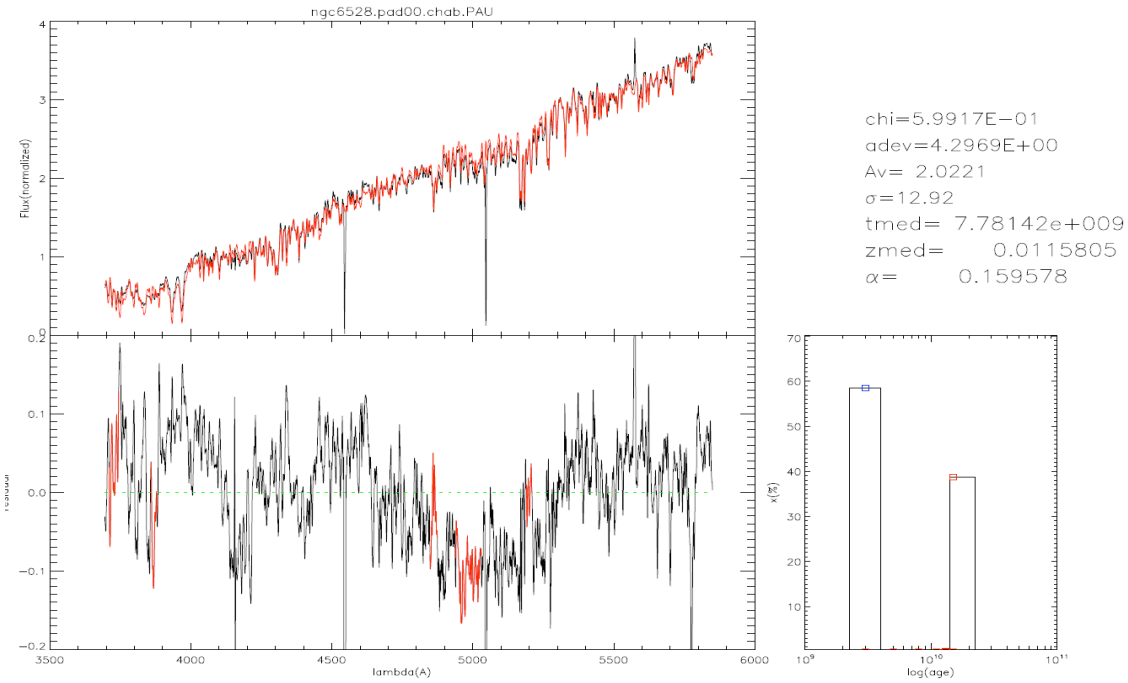


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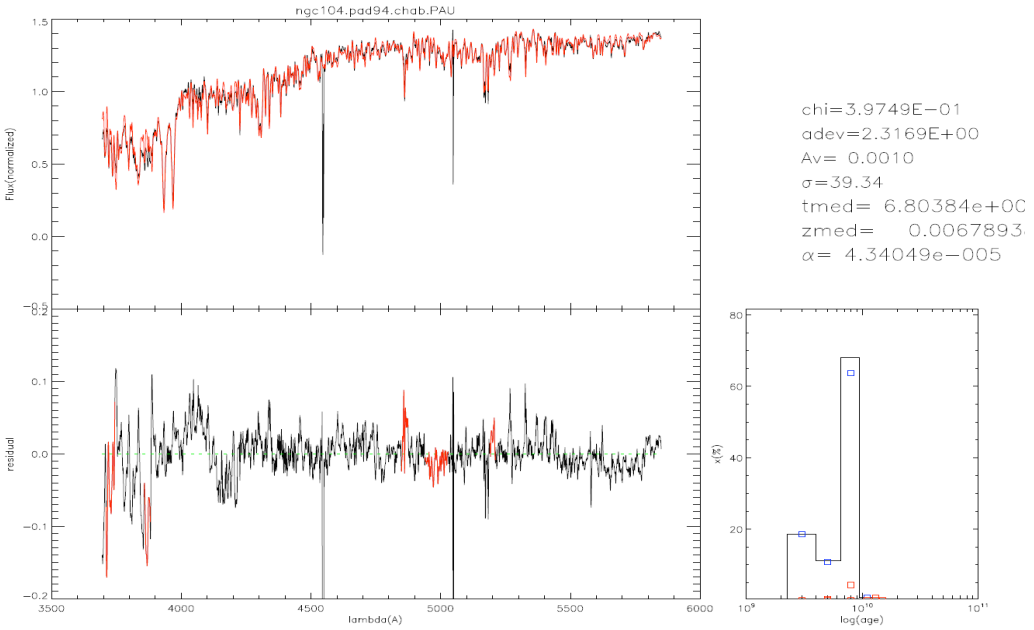
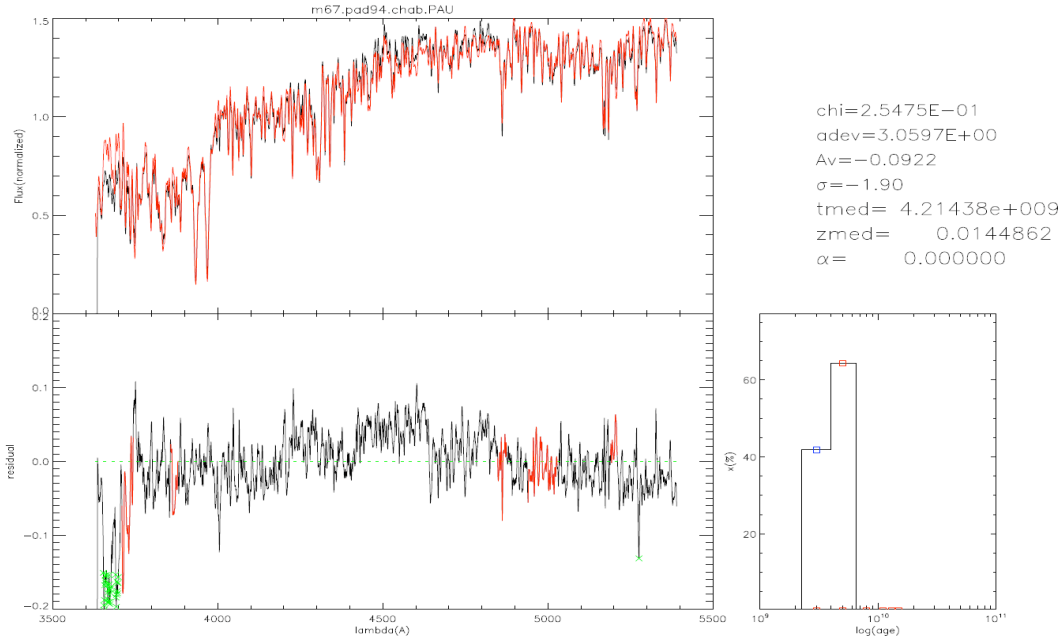
**GALAXEV - Chabrier - Padova 1994 - Coelho et al.**

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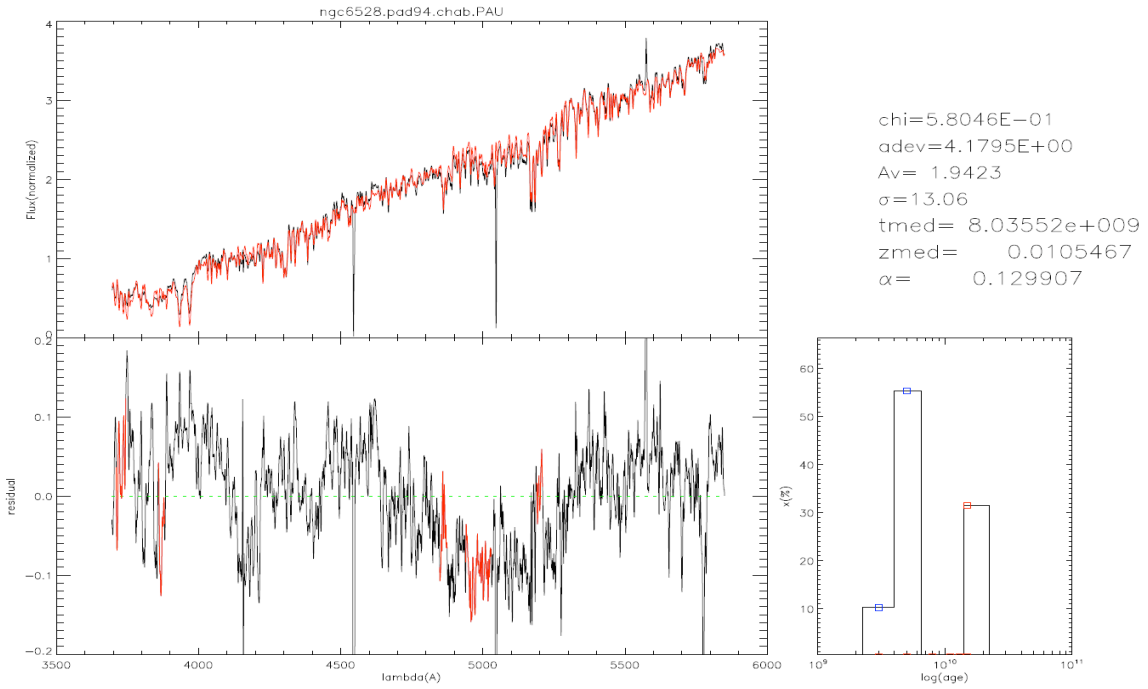


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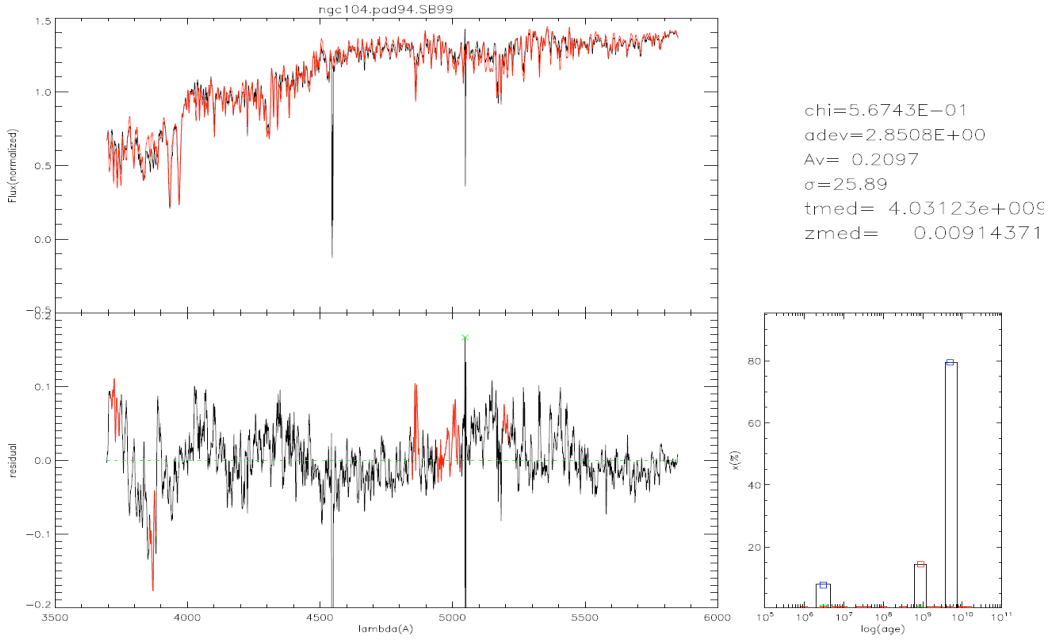
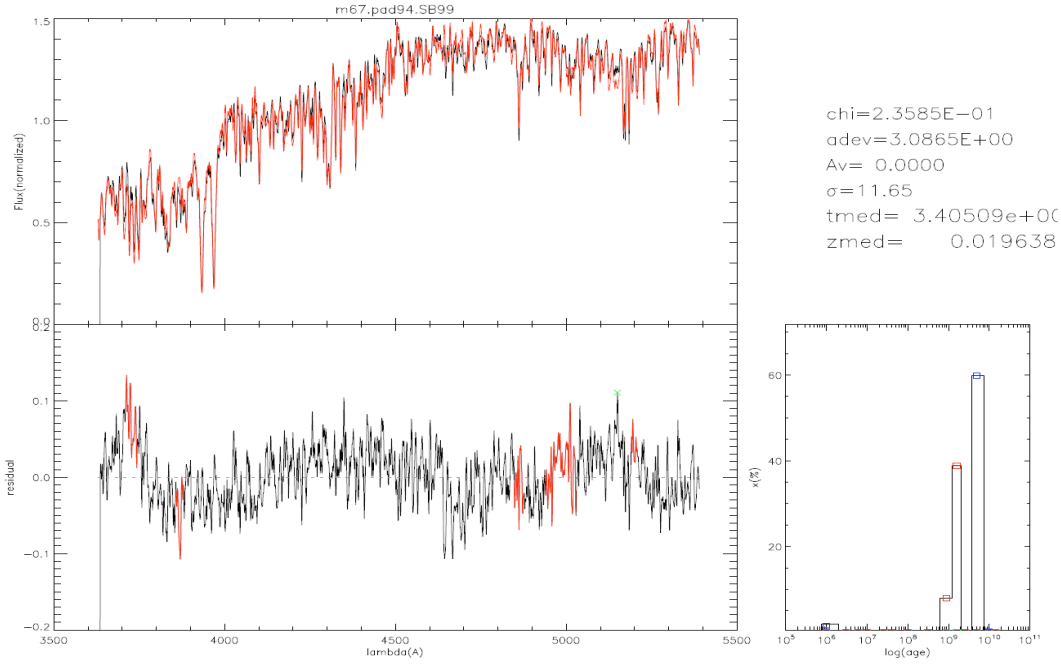
## SB99 - Salpeter - Padova 1994 - Martins et al

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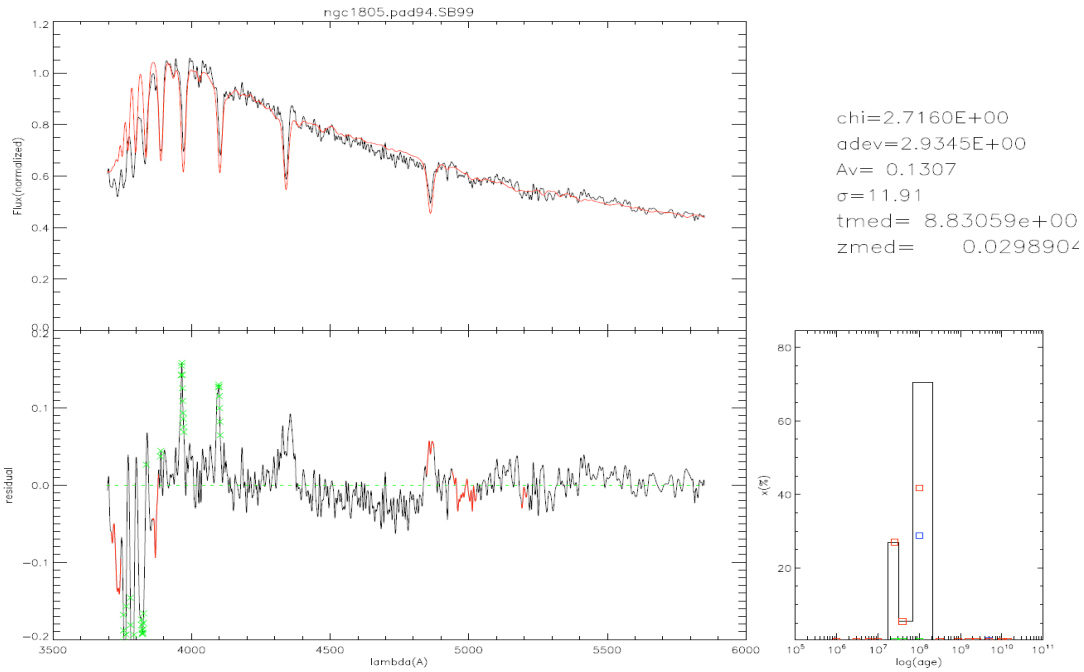


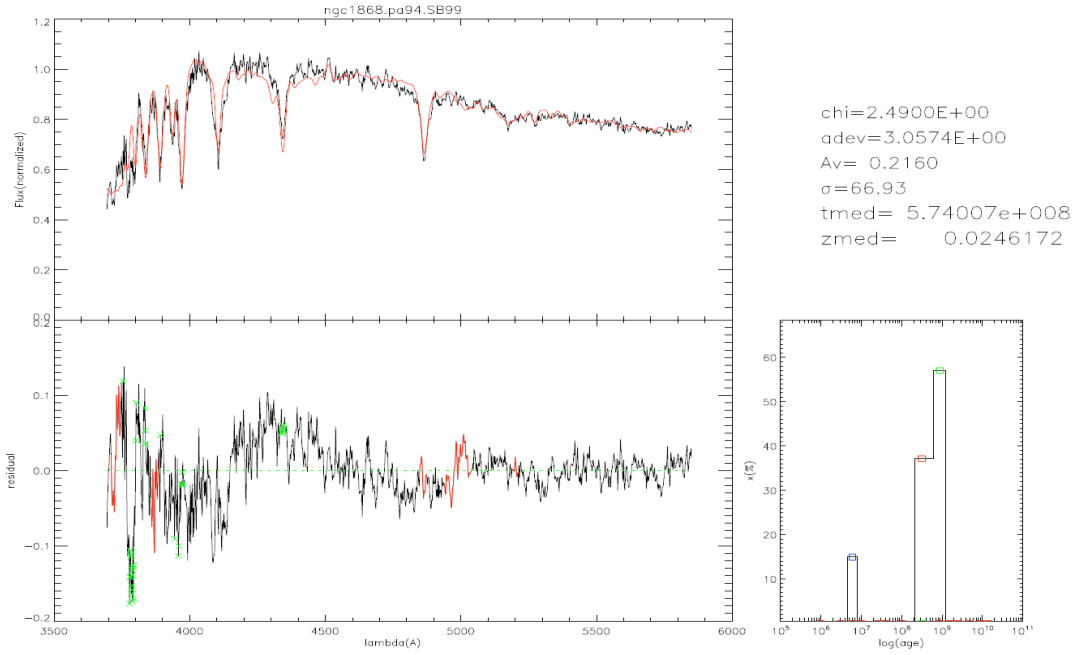


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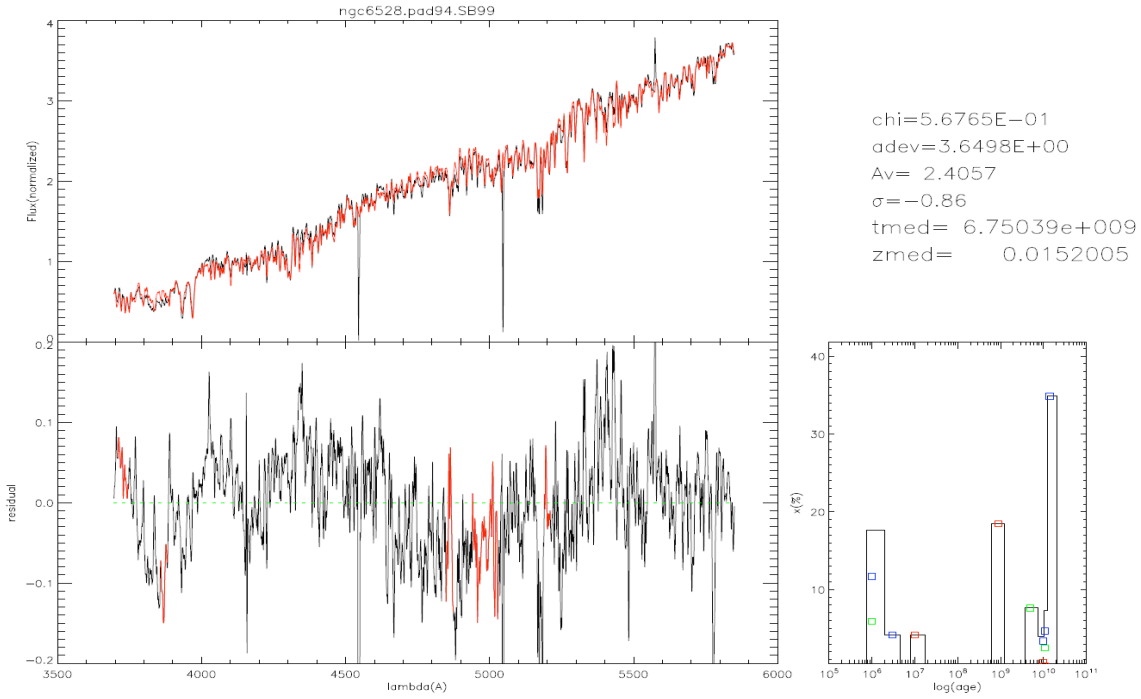


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