CHORIZOS: A COMPLETE PHOTOMETRIC χ^2 CODE

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ABSTRACT

The analysis of Gaia photometry will require the use of techniques capable of transforming the observed colours into physical properties such as temperature, gravity, or extinction. We present here CHORIZOS, a working code (Maíz-Apellániz 2004) that can be used for this task and that tackles the complications associated with it. A beta version is available on request from the author and a fully tested public version is planned for next year.

Key words: Galaxies: star clusters; Methods: data analysis; Methods: numerical; Methods: statistical; Stars: fundamental parameters; Techniques: photometric.

1. DESCRIPTION

CHORIZOS uses as input:

- Photometry (in the form of magnitude or colours with their respective uncertainties) in any combination from an extensive library of filter systems. In the final public version the user will be able to define his/her own filter systems.
- A family of SED models that can depend on one or more intrinsic parameters (such as temperature or gravity). The beta version has a number of them appropriate for stars and clusters; the final version will allow the user to define his/her own SED families.

CHORIZOS performs the following steps:

1. It extinguishes the SEDs using a variety of Galactic and extragalactic extinction laws (parameterized typically by R_{5495}) for colour excesses E(4405−5495) from 0.0 to 5.0 to generate the M colours in a parameter mesh of up to N = 4 parameters (e.g., temperature, gravity, extinction, and extinction law).
2. It performs a χ^2 analysis to assign a likelihood to each of the models in N dimensional space by comparing the observed and model colours.
3. It processes the results generated, possibly using restrictions in the parameters (equivalent to Bayesian priors), to obtain derived magnitudes (such as $m_{\rm bol}$) and the associated correlation matrices. It also produces graphical outputs in the form of likelihood contour plots (Figure 1, bottom), Hertzsprung-Russell diagrams (Figure 3), and best-fit-SED + observed magnitude plots (Figure 4).

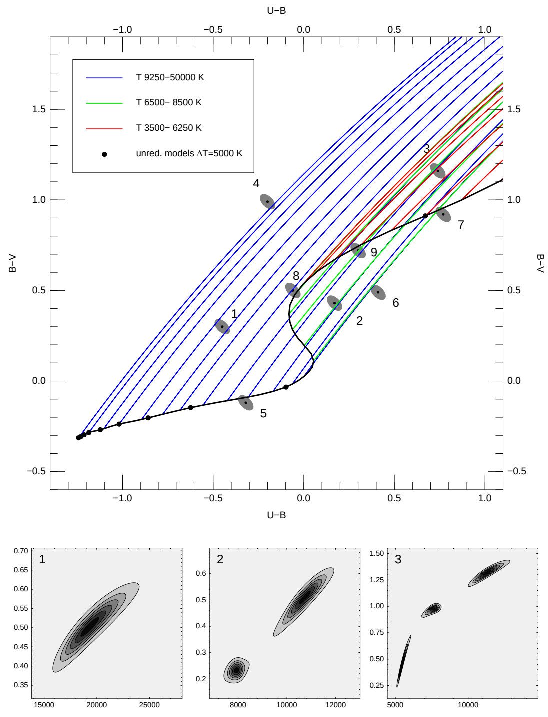

Figure 1. Single and multiple solutions. The simple case (M = 2, N = 2) of solving for temperature and E(4405−5495) for Kurucz main-sequence solar-metallicity models using Johnson $U-B$ and $B-V$ colours is shown in the upper panel. The black line shows the location of the unreddened models (high temperatures are in the lower left) and the coloured ones the extinction trajectories for different temperature ranges. The lower panel shows the CHORIZOS output for stars 1, 2, and 3 above, which have one, two, and three solutions, respectively. In the lower plots, the horizontal axis corresponds to temperature and the vertical one to E(4405−5495).

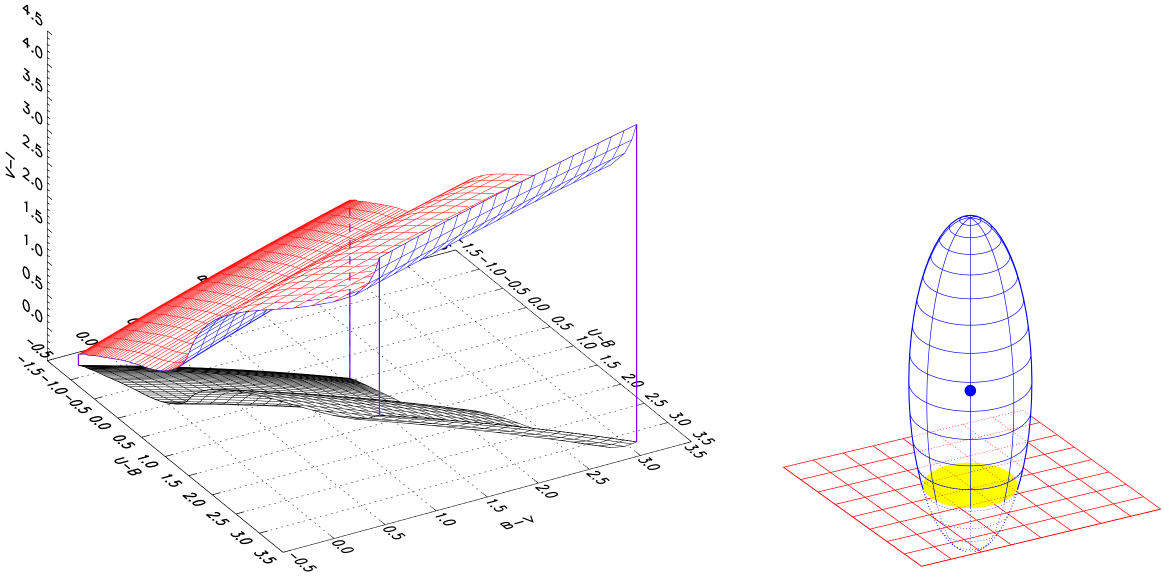

Figure 2. Solving a multidimensional χ^2 problem. We plot here (left panel) the surface defined by main-sequence, solar-metallicity, Kurucz models with R_{5495} = 3.1 extinction (N = 2, temperature and E(4405−5495)) in the M = 3 space defined by the Johnson-Cousins colours $U - B$, $B - V$, and $V - I$. CHORIZOS finds the models compatible with the observed colours by calculating the intersection(s) between the uncertainty ellipsoid and the allowed models (right panel) and assigning likelihoods to the different possibilities by means of the individual χ^2.

The following issues are addressed by the code:

- Each model SED is extinguished exactly in order to reproduce the non-linearity and SED-dependence that are not taken into account by the classical Q method (see Figure 1).
- CHORIZOS can be used either for a real χ^2 case ($M > N$) or for an equation-solving case ($M = N$).
- CHORIZOS finds ALL possible solutions, not only the most likely one, and calculates the associated uncertainties in parameter space. For the case of multiple solutions, the user can select individual ones to calculate their specific characteristics.
- Correlations between colours are correctly accounted for in the χ^2 analysis.
- The grid size can be adjusted to account for the measurement precision. CHORIZOS warns the user if the grid used is too coarse.
- The grid can be extended beyond the original parameter range if needed (e.g., if we have a population of objects with near-zero extinction and we want to avoid biases in the measurement of that quantity, negative extinctions can be included).
- Since the native filter systems are used, no transformation (e.g., from WFPC2 F336W to Johnson U) is necessary, thus improving the quality of the results.
- Using a test mode, the code can be used to check for possible parameter degeneracies for a family of SED models and a given set of filters and measurement uncertainties.

2. APPLICATIONS

Applications for CHORIZOS can be divided into two groups: calibration and data analysis. Examples of calibration applications are:

- Testing filter sets to find the optimal combination that resolves an SED family into its components. This test mode has a direct application to Gaia.
- Finding zero-points and testing throughputs for filter sets by comparing spectrophotometry with photometry. Maíz-Apellániz & Barbá (2005) do this with CHORIZOS for optical filters and early-type stars.

Examples of data analysis applications for which CHORIZOS has been applied are:

- Creation of ‘theoretical’ Hertzsprung-Russell diagrams for stars directly from magnitudes (see Figure 3 and Arias et al. 2005 and Úbeda et al. 2005).
- Identifying whether an object belongs to one or another class of objects. See Figure 4 and Maíz-Apellániz et al. (2004).
- Measuring ages and extinctions of clusters (Úbeda et al. 2005 and Melo et al. 2005).

A colour version of this poster is available at `http://www.stsci.edu/~jmaiz`.

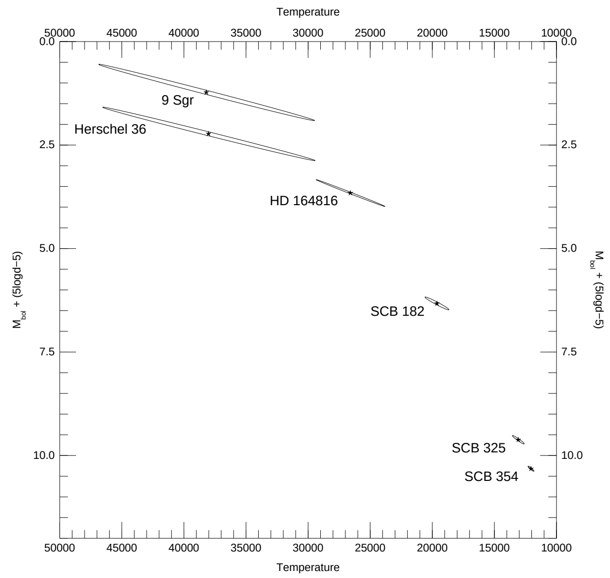

Figure 3. H–R diagram produced by CHORIZOS from the data in Arias et al. (2005) for six obscured early-type stars. The code produces likelihood ellipses in parameter space, in this case temperature and $m_{\rm Bol}$.

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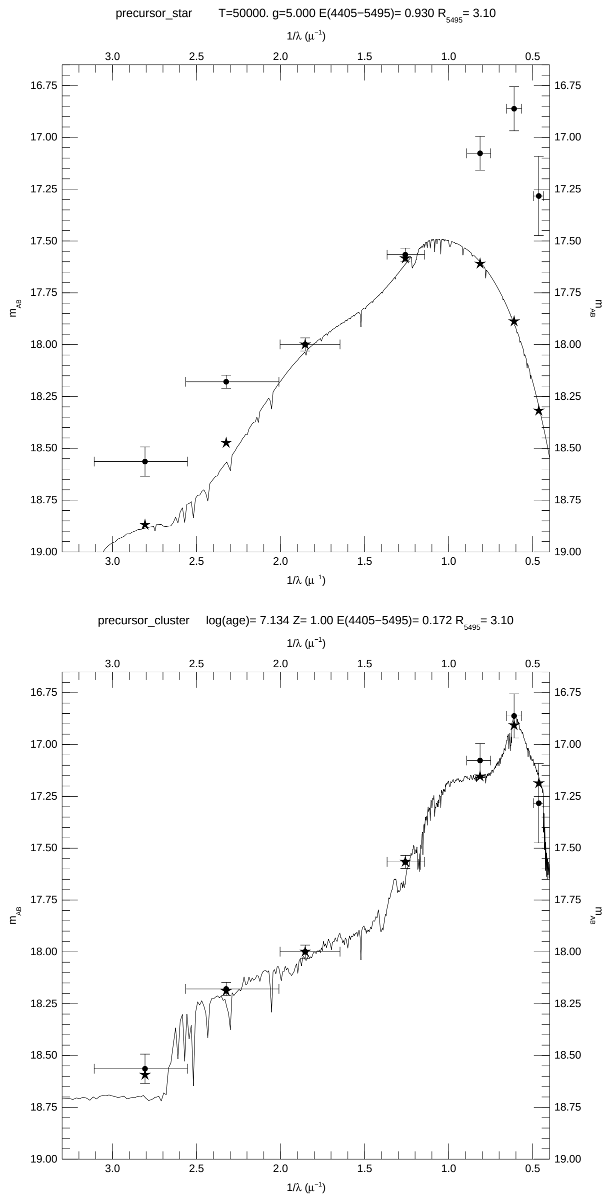

Figure 4. Discerning between different families of objects. The upper plot shows the measured magnitudes (points with error bars) and best-fit SED using stellar models for Sandage 96, the progenitor of SN 2004dj. The reduced χ^2 *of 43 indicates that the object could not have been a single star. On the other hand, a cluster SED provides an excellent fit (reduced* χ^2 *of 0.3, bottom panel), allowing for an accurate measurement of the cluster properties (see Maíz-Apellániz et al. 2004 for details). Stars mark the magnitudes which correspond to the best-fit SED.*