Population Synthesis Models in 2D/3D: some rules

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Abstract

Population synthesis models are a tool extensively used to make inferences about the evolutionary status of stellar populations. In this work I examine the implicit priors assumed to obtain inferences by comparing observational data with populations synthesis models. As a result from this kind of study, I show how a higher spatial resolution can be used to obtain better *global* (but not spatially detailed) properties of the system.

I also show that a pixel-by-pixel (or IFU by IFU) analysis would provide biased results unless they take into account the correlations of stellar populations between different resolution elements (pixels or IFUs) and a prior hypothesis on the projected stellar mass distribution (equivalent toa prior hypothesis on the star formation history)

Warning

If you still believe that, without actual knowledge of the stellar content. you can *determine* the system properties (it means, the Initial Mass Fucntion is a deterministic law instead a probability density function) you are looking for incorrect answers in the incorrect place, and this is not a poster you will like.

The description of ensembles can be only archived in a probabilistic framework;, hence by probability density functions (pdf). It includes synthesis models, chemical evolution models and so on. And, there is not an unique solutio, but a distribution of solutions (the resulting pdf)

The Basic framework

(Cerviño & Luridiana 2006, A&A 451, 475)

I. Synthesis models provide a description of the pdf of the stellar luminosity, that is the probability that ***a star*** in a system with given star formation history (age, metallicity) has a given luminosity. Usually only the mean of such distribution is provided by models.

$$\varphi_{\rm L}(\ell|t,Z) \quad \text{although usually only is given} \quad \langle \ell|t,Z\rangle$$

II. The pdf that describe stellar **ensembles** can be obtained by the combination (by recursive convolutions) of the pdf of single stars. Actually, mean values of the resulting population pdf can be related by simple scale relations with the stellar pdf ones.

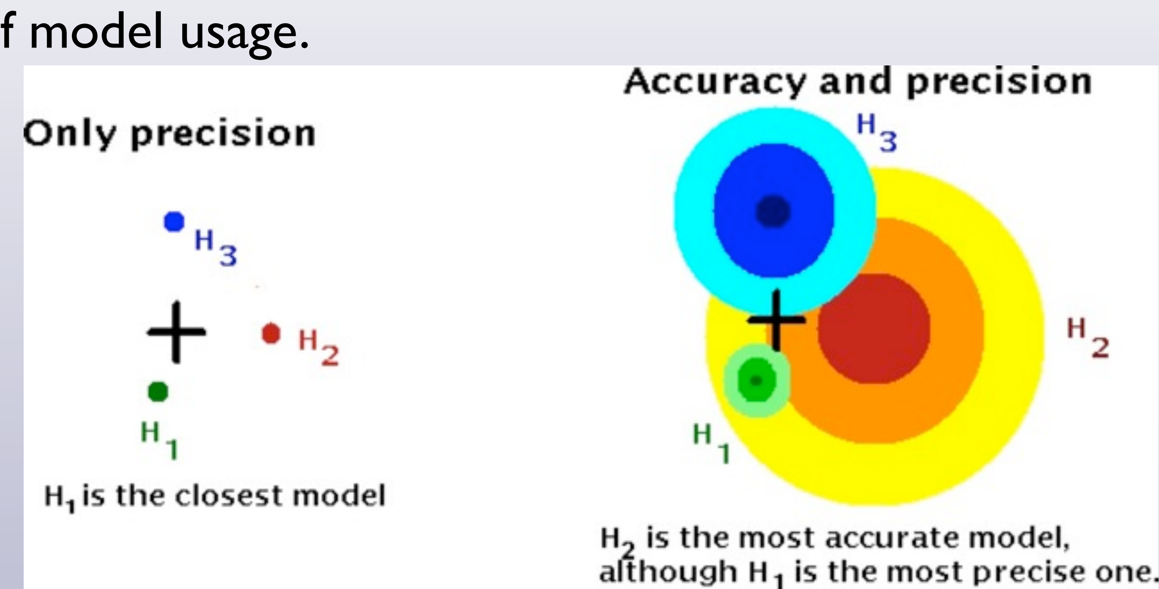
$$\varphi_{\rm L_{tot}}(L_{\rm tot}|t,Z,N_{\rm tot}) = \overbrace{\varphi_{\rm L}(\ell|t,Z)\otimes\varphi_{\rm L}(\ell|t,Z)\otimes\,...\,\otimes\varphi_{\rm L}(\ell|t,Z)}^{N_{\rm tot}}.$$

$$\langle L_{\rm tot}|t,Z,N_{\rm tot}\rangle = N_{\rm tot}\,\times\,\langle \ell|t,Z\rangle$$

Implications

(Cerviño & Luridiana astro-ph/0711.1353, 0711.1355)

I. Not all wavelengths are equally relevant, but each (***theoretical***) combination of t, Z and Ntot has its own ***metric of fitting*** increasing the accuracy of model usage.



II. Such metrics of fitting must be used in the fit of stellar data has a prior information. Actually it **breaks the age-metallicity degeneracy** which appear when only the mean value of the pdf(t,Z,Ntot) is used (it is equivalent to the claim that surface brightness fluctuations do, but in a more general context, e.g. Buzzoni astro-ph/0509602)

Inference and the Bayes' Theorem

I. Observationally we observe the total luminosity and we want to infer the system properties, but

$$\varphi_{\rm SFH}(t,Z,N_{\rm tot}|L_{\rm tot}^{\rm obs}) \;\text{ is not the inversion of }\; \varphi_{\rm L_{tot}}(L_{\rm tot}|t,Z,N_{\rm tot})$$

Instead, we must use the Bayes' theorem:

$$\varphi_{\rm SFH}(t,Z,N_{\rm tot}|L_{\rm tot}^{\rm obs}) = \frac{\varphi_{\rm L_{tot}}(L_{\rm tot}|t,Z,N_{\rm tot})\,\Phi(t,Z,N_{\rm tot})}{\int\int\int\varphi_{\rm L_{tot}}(L_{\rm tot}|t,Z,N_{\rm tot})\Phi(t,Z,N_{\rm tot})\,{\rm d}t\,{\rm d}Z\,{\rm d}N_{\rm tot}}$$

Which imply to use our prior knowledge about:

$$\Phi(t,Z,N_{\rm tot}) \;\; that\ is\ the\ (unresolved\ version\ of\ the) Star\ Formation\ History\ itself!!$$

II. In a single observation we have no information about such a prior, so actually a flat prior is assumed. But in a 2D/3D observation (pixels, IFUs) we have it !! (at least a first order one)

a. We know that the SFH varies along pixels/IFUs, and we have galaxy models (dynamics) that gives us an idea about how this variation is, i.e. a model where SFH = SFH(x,y).
b. We know that, dynamically, the older the population the more mixed in the whole galaxy it wil be.
c. We have a description of how Ltot is distributed in pixels/IFUs with similar values of the SFH!! (and we know that not all total luminosities will have an equal mean value, but that they are *distributed* around it following a defined pdf.

$$\mathrm{SFH}(x,y) \rightarrow \Phi(t,Z,N_{\rm tot})$$

Rules of thumb

(1) *Do not aim to obtain "detailed" information about* what happens in *a* ***particular*** *pixel/IFU*: the real solution depends also on whats happens with the global galaxy (i.e. the prior about the SFH, implicit in any inference)

(2) Consider *each pixel/IFU* element as a data *element that is* ***sampling*** *the (theoretical) distribution* of luminosities of the stellar ensemble with the given physical conditions (Remember: not all elements will be coincident with the mean value of such distribution!!)

(3) Take advantage of the global distribution: again, the point is to *fit the theoretical pdf*, not the mean value. In addition, since the pdf shape depends on the number of stars in the resolution element, combine elements to obtain new sampled distriutions (with a larger number of stars in the resulting pixel elements)

(4) Iterate: The inferences depends on the assumption about the SFH; if the global analysis provides a different SFH than the one used has input, iterate the process until a self-consistent SFH is obtained.

In summary: the global results obtained by summing up all the pixels/IFUs must be compatible with the global results obtained from the analysis of the ensemble of the individual pixels/IFUs; it means, *the global properties that would be inferred from the system should not be dramatically dependent on the resolution!!*

2D/3D observations would provide an increase on the accuracy (and maybe precision) about the knowledge we would obtain from unresolved situations. And of course, the access to more details. Whatever the case, the details can not modify dramatically the global results, as well as the details of a tree can not modify dramatically the description of a forest.