Scientific Report. GREAT grant.

Visit of Maria Czekaj to Institute UTINAM, Besançon Observatory,
15 - 27 May 2011

Title: Galaxy modelling for preparing the Gaia analysis

Supervisors: Annie Robin, Francesca Figueras, Xavier Luri

Purpose of the visit: The objective of this thesis is to develop a new version of the Besançon Galaxy Model able to handle variations of the star formation rate in different populations, initial mass function and evolutionary tracks, as well as binaries and improved kinematical description. A visit of Maria Czekaj to the UTINAM Institute in Besançon allowed discussions and intensive collaboration with Annie Robin.

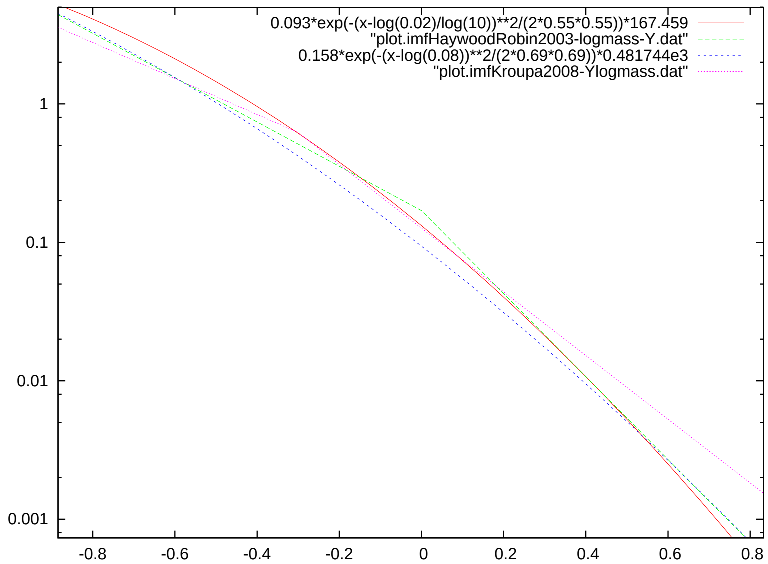
Description of the work carried out during the visit:

During the visit in question we have solved many pending problems and significantly moved forward in our research. Various issues have been investigated.

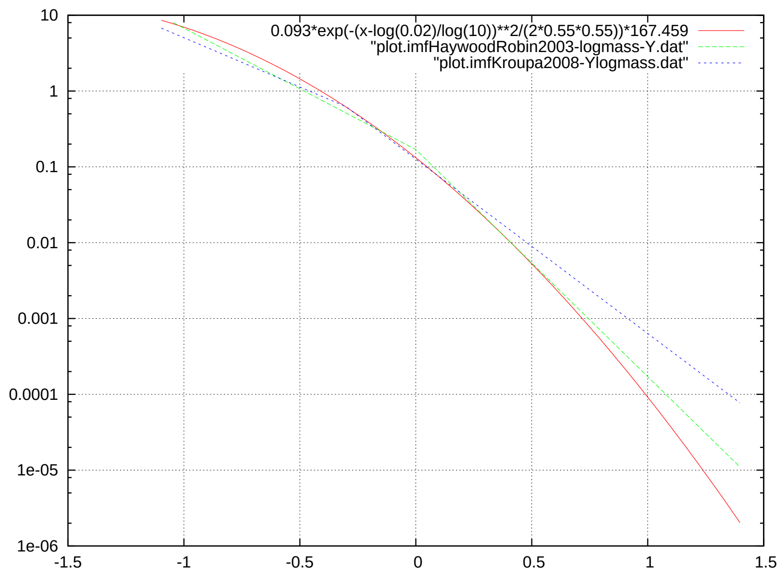
1. **0n the IMF.**
   We found it necessary to check the results of Chabrier in that field and compare to the other IMF scenarios already tested by us in the model (among others Kroupa 2008 and Haywood 1997). All the IMFs we have considered until now have a form of a simple power law
   $$\xi(m) = m^{-\alpha}, \tag{1}$$
   while the approach of Chabrier is different, because he models the IMF by a log-normal distribution. In the abstract of his paper from 2003 he says: "As a general feature, **the IMF is found** to depend weakly on the environment and **to be well described by power-law form for $m > 1M_\odot$ and a log-normal form below**, expect possibly for early star formation conditions ". He specifies there an analytical formula for the IMF of low masses. In his paper from 2005 he revises the values of parameters in that formula due to new data constraints, such that it has a form of Eq. 2.
   $$\xi(log\ m) = 0.093 \times exp(-\frac{(log\ m - log(0.02))^2}{(2 \times 0.55 \times 0.55)}) \tag{2}$$
   We have compared both Chabrier's functions (2003 and 2005) with the IMFs of Kroupa and Haywood (as from the previous analysis we favoured those solutions), see Fig. 1. The log-normal functions were firstly normalized. We contemplated that plot and arrived to very interesting conclusions. Namely, the log-normal IMF of Chabrier 2005 gets close to the Kroupa IMF for stars below and around 1 $M_\odot$, while for higher masses is actually similar to Haywood IMF. And because we already concluded from the previous work, that Kroupa's IMF gives the best fit to Tycho data apart from the high masses, where Haywood's slope performs better, we could say, that the combination of both functions gives the satisfying solution we are looking for and that it is very close to the one proposed by Chabrier 2005.

   So what we did subsequently was to combine the IMFs of Kroupa and Haywood by finding their intersection above 1 $M_\odot$ and appliying the slope of Kroupa below that value and the one of Haywood above that value.

   This is how we got the Kroupa-Haywood IMF:
   $$\alpha = \begin{cases} 1.3 \pm 0.3 & 0.08 <= M/M_\odot < 0.5 \\ 2.3 \pm 0.5 & 0.5 <= M/M_\odot <= 150 \end{cases}$$
   We chose it to be our IMF scenario giving the best fit to data until now.



a) **dN/dm(log m)**



b) **dN/dm(log m)**

Figure 1: Comparison of Kroupa 2008, Haywood 1997, Chabrier 2003 and Chabrier 2005 IMFs.

In the Fig. 2 we show the comparison of the observed local Luminosity Functions from Jahreiss (1997) and Kroupa (2000) with the synthetic one when the new Kroupa-Haywood IMF was applied. For bright stars the new LF follows the one of Haywood and at around 3 $M_\odot$ is switches to Kroupa 2008. We still do not reproduce well the faint stars, but this part can not be constrained by our Tycho sample, due to the cut in magnitude we perform. We find this solution satisfying at the moment. The faint part of the LF could be fitted better in the future using other data sets.

We then have compared with Tycho-2 data the star counts and BV colour distributions for six different directions in the sky imposing the new IMF. The conclusions were that we accepted the Kroupa-Haywood IMF for the rest of our analysis, as the fit we get is not bad and as it is very probable that the remaining discrepancies in the colour

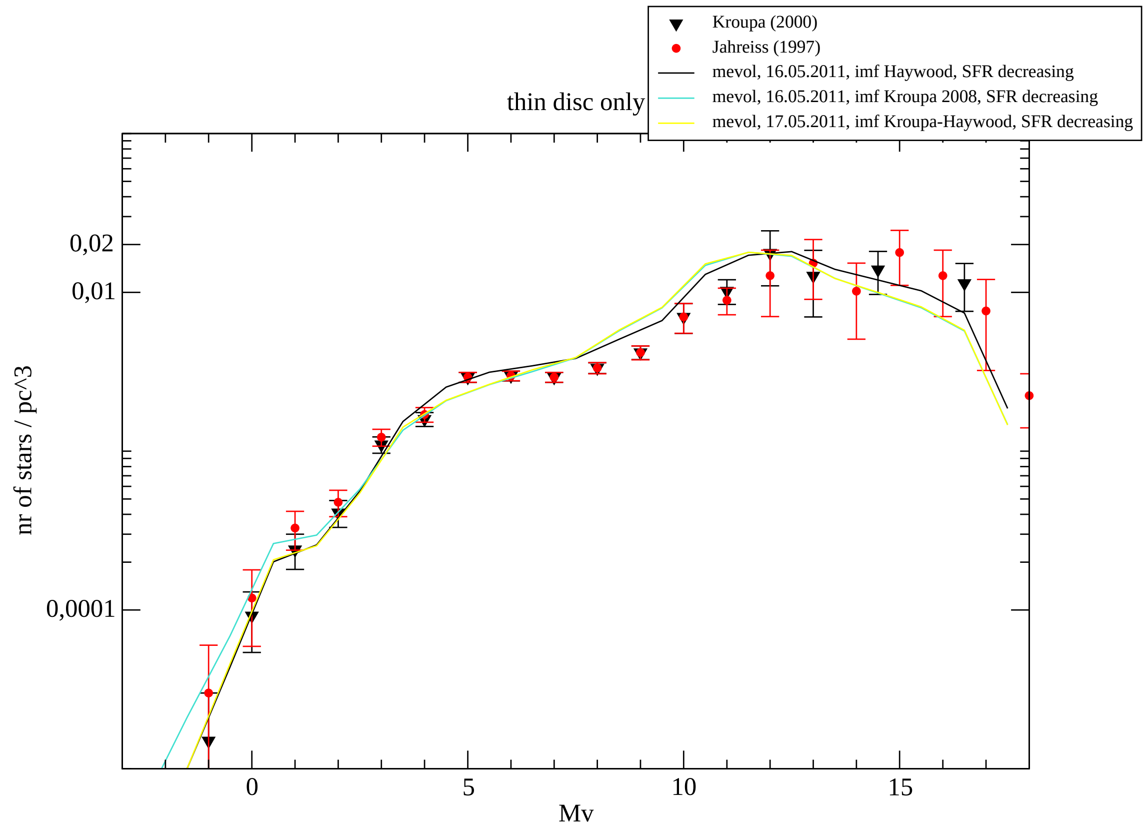


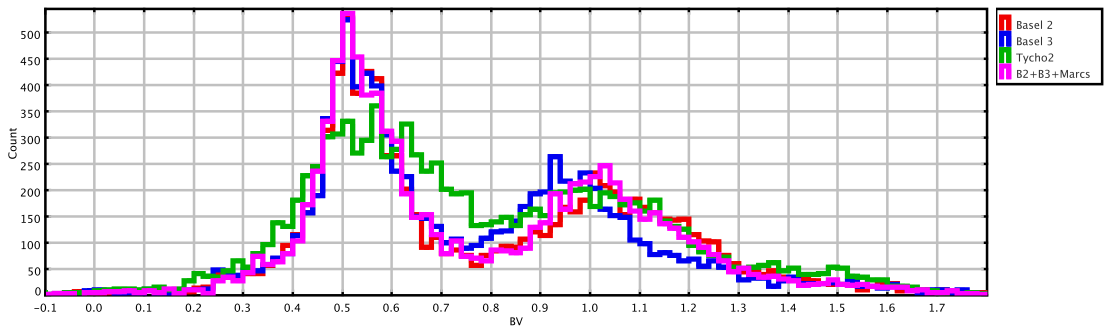
Figure 2: The LFs obtained with the Kroupa, Haywood and Kroupa-Haywood IMFs.

distribution shape are of a different matter.

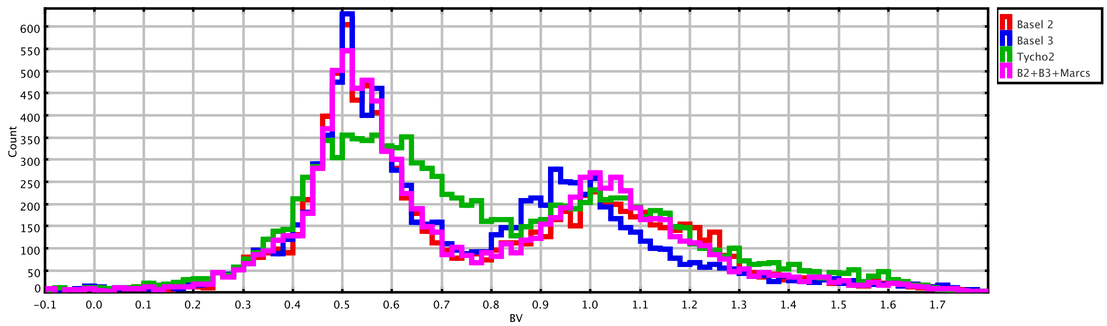
2. **Atmosphere models.**

Our model works with two sets atmosphere models, Basel 2 and Basel 3, and we are still in the phase of testing which one performs better. Throughout our analysis we have seen that the Basel 2 is redder than the Basel 3 when considering the red peak of our BV distributions, while the data is placed between them. We have also concluded that Basel 2 is better at lower metallicities, because towards the Galactic poles it gives very good fit and that Basel 2 is better at solar metallicities. Consider the Fig. 3. From previous investigations we knew that the Marcs models for giants fall in between two Basels. Knowing that we have made an experiment. We have combined the solutions of atmosphere models in such a way that we have decided to use Basel 2 for all metallicities apart from the solar one. The file corresponding to the z=0.02 was taken from Basel 3, however 15 points of the grid modelling the giants were replaced by the MARCS solution. We performed the simulations in six directions in the sky. The results are given in the Fig. 3 and Fig. 4.

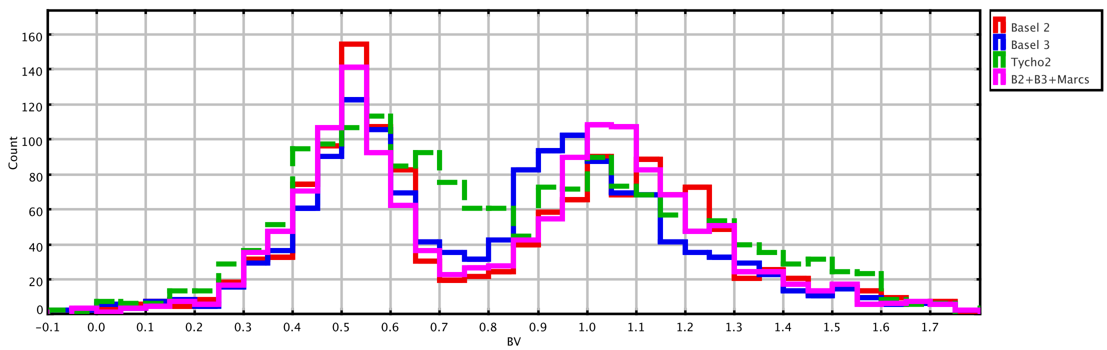
CONCLUSION FROM THE PLOTS: The combination of atmosphere models gives a very good solution at the poles. At lower latitudes as expected it places the red peak between both Basels, what is in the agreement with data. However it produces more stars there, as they were taken from the tails of distribution. Sometimes this effect is stronger sometimes weaker, so it depends strongly on the direction and type of stars we create. We decided to test the atmosphere models more intensively.



a) North Galactic Pole

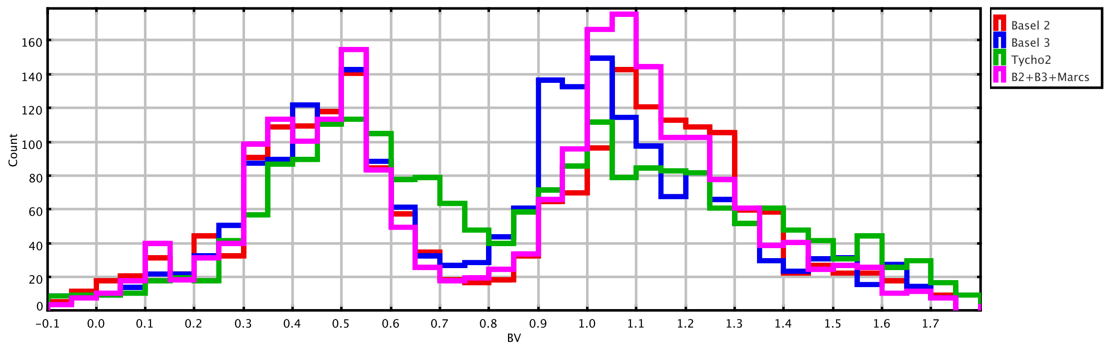


b) South Galactic Pole

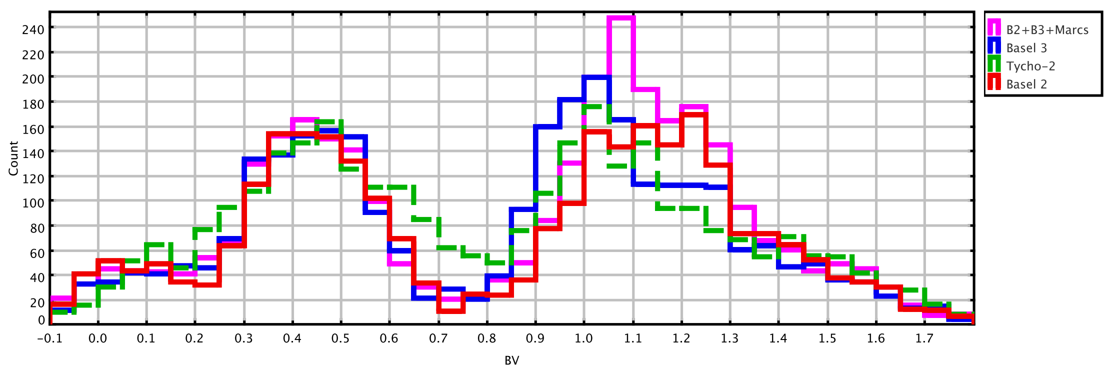


c) **N182**. l=(20.0; 40.0), b=(40.0; 50.0)

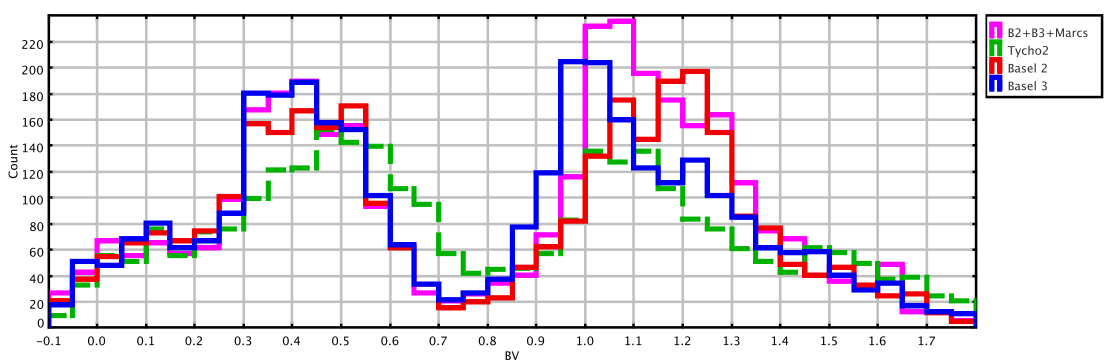
Figure 3: Comparison of atmosphere models.



a) **S114**. l=(50.0; 60.0), b=(-30.0; -50.0)



b) **N100**. l=(270.0; 280.0), b=(10.0; 20.0)



c) **S082**. l=(90.0; 100.0), b=(-10.0; -20.0)

Figure 4: Comparison of atmosphere models.

3. **New thick disc parameters.**

   Since thick disc population is not negligible in our analysis we thought it is important to apply an update to the thick disc model, which Annie Robin has done some time ago. It is a change in the density calculation and it is discussed in the paper Reyle & Robin 2001. The Eq. 1 of that paper expresses the density law of the thick disc, which is assumed to be truncated exponential, at large distances it is exponential and short parabola. It is discussed there that there are three parameters defining the density along the z axis and changing their values, was the change we have applied.

   - the distance above the plane x_l from 400 to 72.0 pc
   - the scale height h_z from 800 to 1200.0 pc
   - reduction of the density from 1.0 to 0.25.

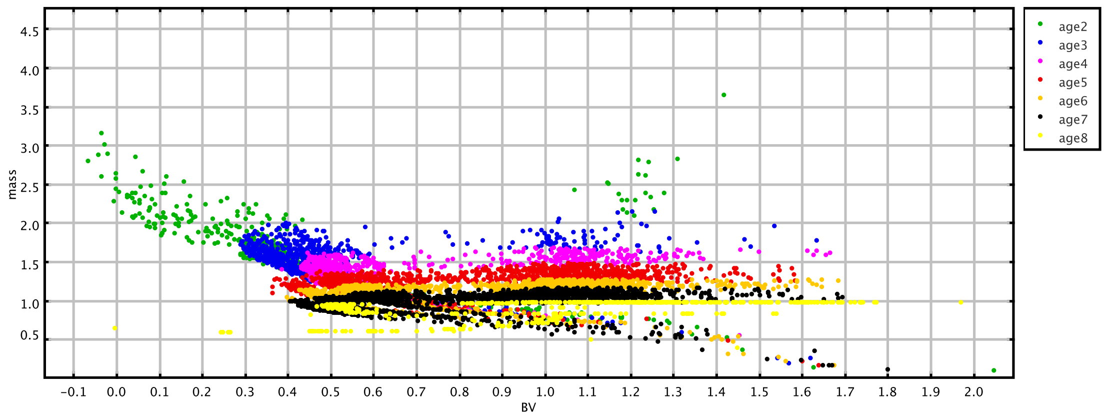
   CONCLUSIONS: After applying those changes the star counts in the six directions, which are under investigation have changed. As one could expect the biggest difference is seen when looking at the poles, because it is there where one finds the thick disc most abundantly. At lower latitudes the difference between old and new thick disc density models does not play an important role, however still one could notice a general tendency caused by the applied change, namely the number of objects has decreased. And in fact it should be like that, because by changing the above listed thick disc parameters we have extended it.

4. **The BV-mass relation.**

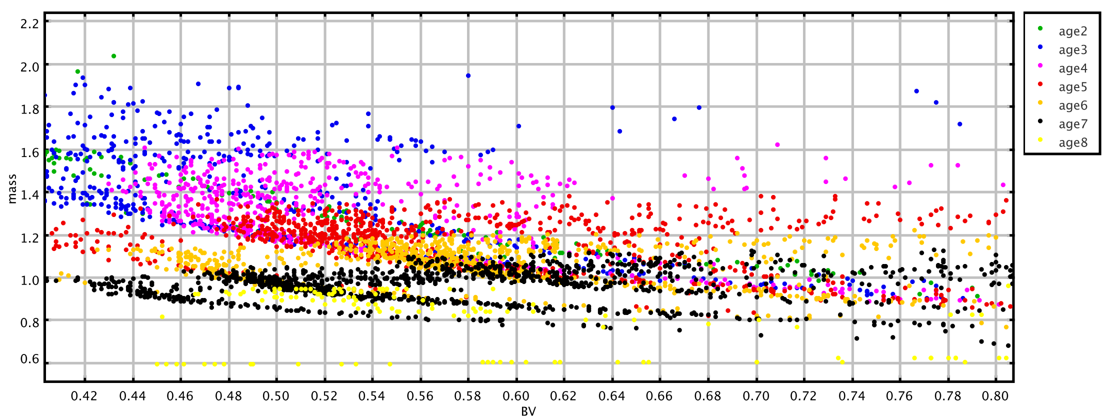
   The last days of the visit were dedicated to the investigation of the discontinuities, which we have detected in the BV - mass relation. As an example see Fig. 5.

Future collaboration with host institution:

Continuous cooperation between both parties is maintained. According to the project plan June and July are two final months of our investigation and then a PhD student will start writing the thesis. Recently we have applied to the European Science Foundation for the third and the last one in our case financial support. This time we asked for the exchange grant. It would be the last visit of Maria Czekaj to the UTINAM Institute in Besançon dedicated to writing a paper about the new model release and the comparisons with data we have made throughout our project.



a) GNP, BV-mass relation



b) GNP, BV-mass relation BV=(0.4;0.8)

Figure 5: The BV-mass relation for the GNP. Age population distinguished.