Preparing the Besancon Galaxy Model for the comparison with Gaia data

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The construction of a dynamical model of our Galaxy is one of the primary goals of the Gaia mission.

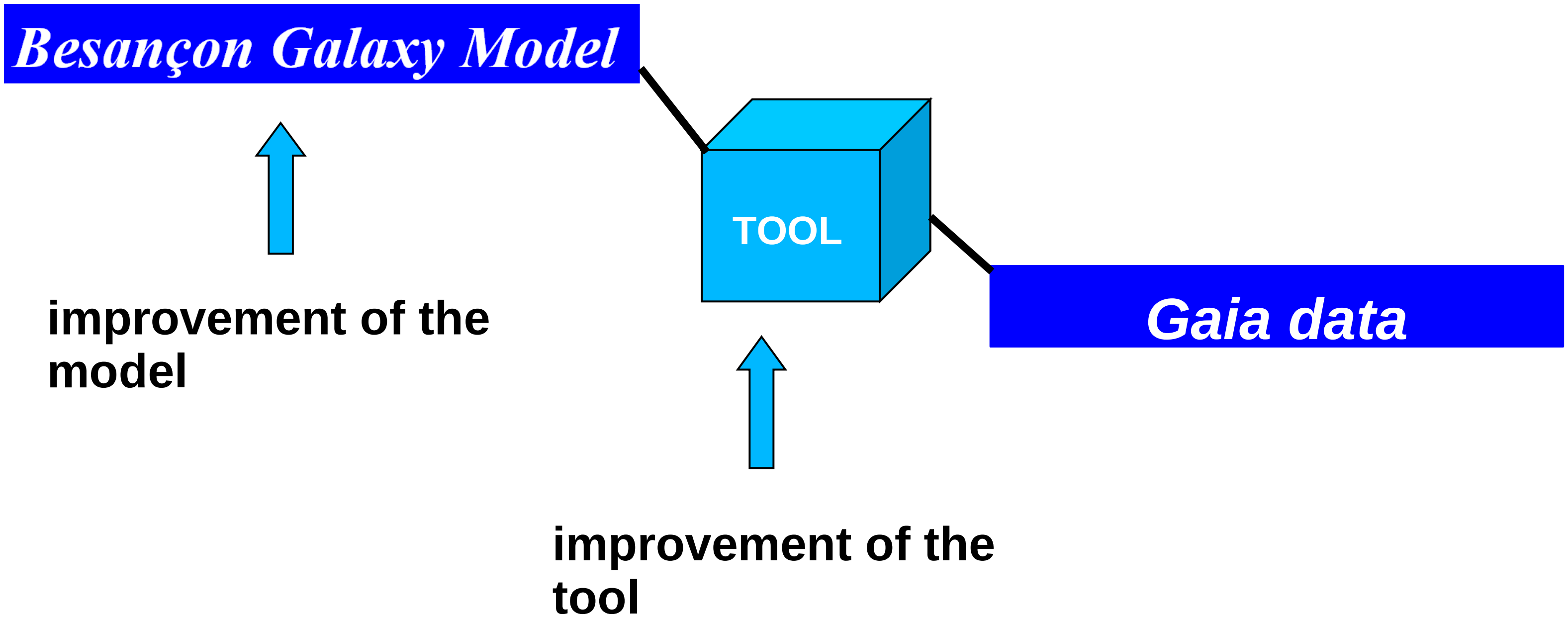
Kinematic and star count data, together with the physical parameters of the stars - ages and metallicities, will allow to characterize our Galaxy populations, and from that, the overall **Galactic gravitational potential.**

Φ

Observables → **kinematics** ↔ **local gravitational potential** ↔ **dark matter**

Observables → **Stellar counts** ↔ **IMF SFR** ↔ **total mass in stars**

To be prepared for an optimum exploitation of the huge amount of Gaia data.



The present research project, in the context of the Gaia CU2 coordination unit, will allow refining the simulation of the sky as observed by Gaia. The current Gaia simulator is based mainly on Besançon Galaxy Model. **Further evolution and complexification of this model is desired!**

Aim of the project:

1. Improve the kinematics of the Besançon Population Synthesis model.
2. Examine different IMF and SFR scenarios.

Besançon Galaxy Model

Different scenarios of Galaxy formation and evolution.

Knowledge about the formation and evolution of stars and their atmospheres.

Dynamics

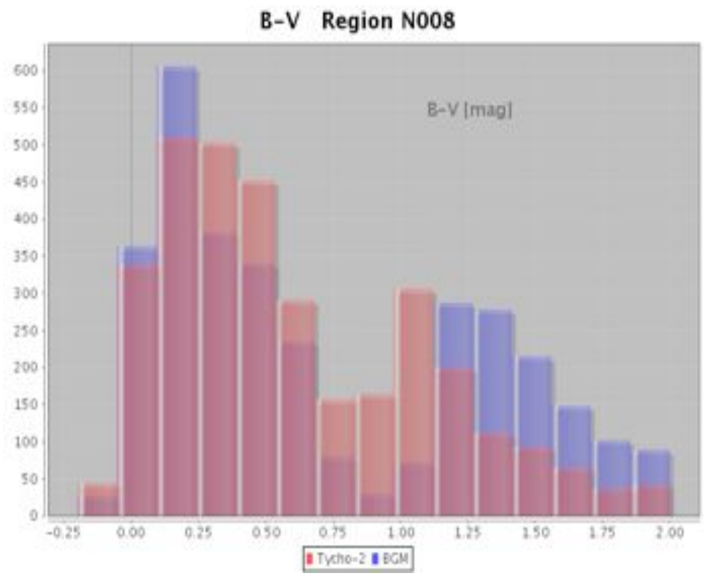
compared with survey observations of different types (photometry, kinematics, abundance distributions).

Links evolution with kinematics and dynamics by the stellar ages.
Dynamical self-consistency
Stars belong to 4 basic populations: the thin disk, the thick disk, the stellar halo and the bulge.
Each group is characterized by its own SFR, IMF, evolutionary tracks, kinematics, and metallicity.

A. Robin & M. Creze, 1986; Bienayme et al. 1986; M.Haywood et al. 1997; Robin et al. 2003;

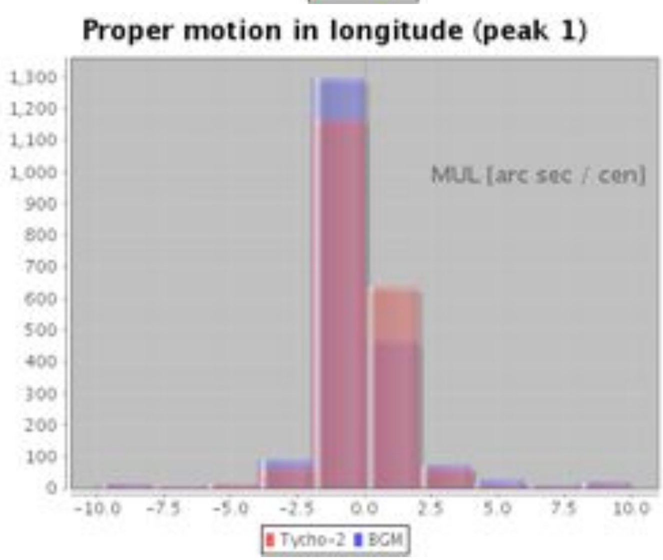
Tycho-2 catalogue ⟷ ? ⟷ ***Besançon Galaxy Model***

The <u>whole sky</u> comparison for a magnitude limited sample!



Stars up to V = 11 mag
(catalogue completeness ~ 99%)

Apprx. 860 000 stars in 472 fields

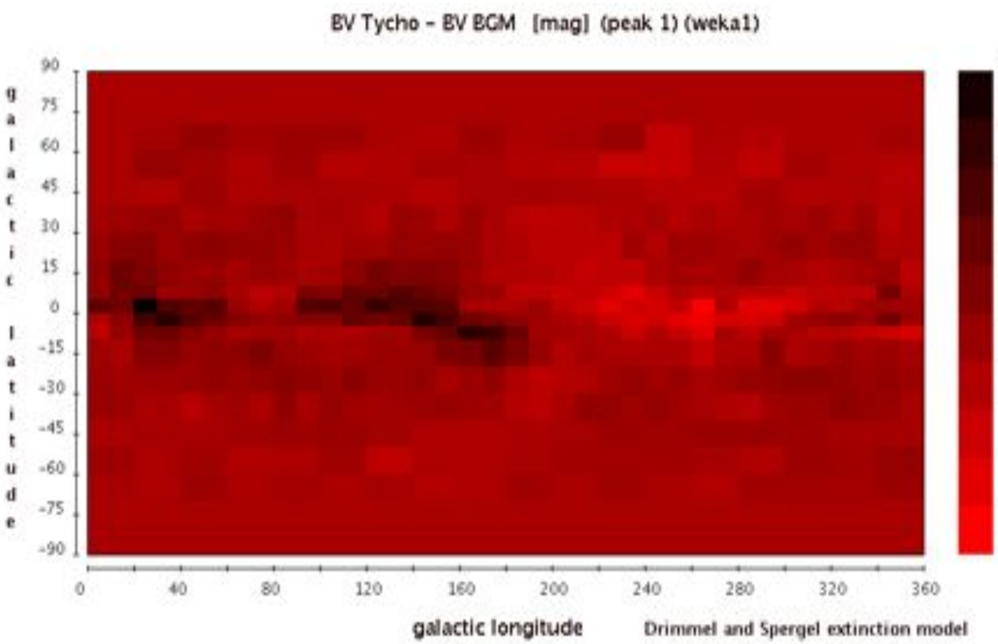


Comparison of

- **Star counts**,
- **(B-V)** colour and
- **proper motion**

distributions.

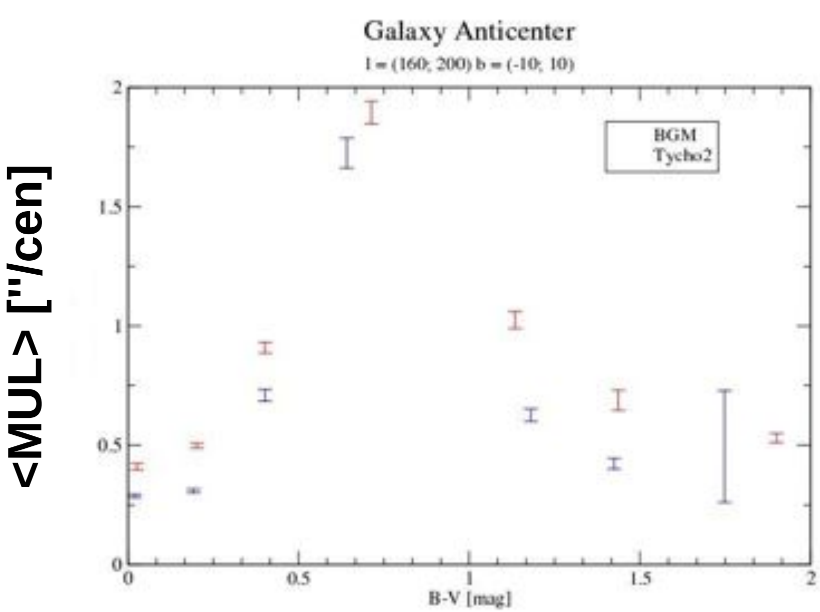
First analysis

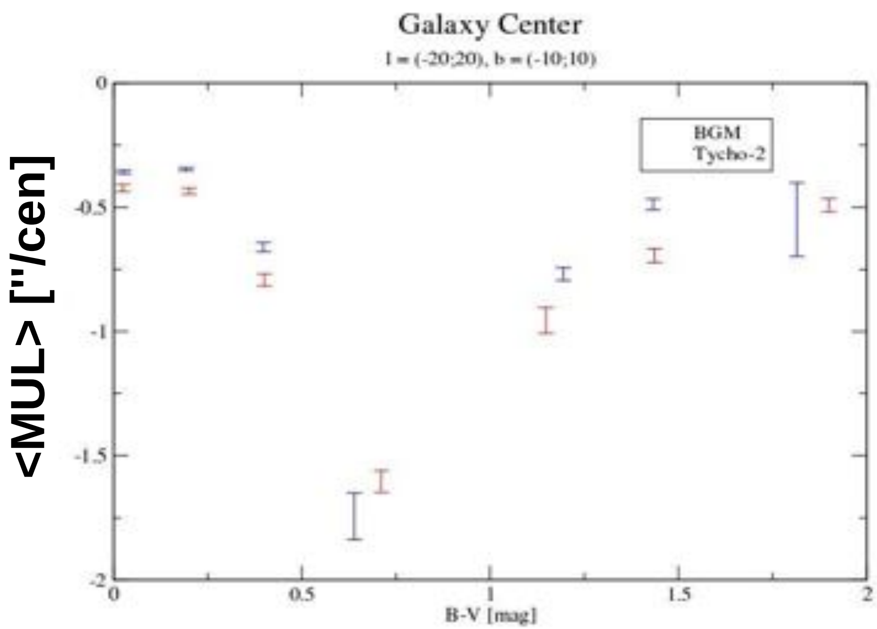


All Sky Plots and
more detailed examinations:

- Extinction models comparison;
- Star counts analysis;
- Proper motion analysis;

- **BGM and Tycho show significant differences.**

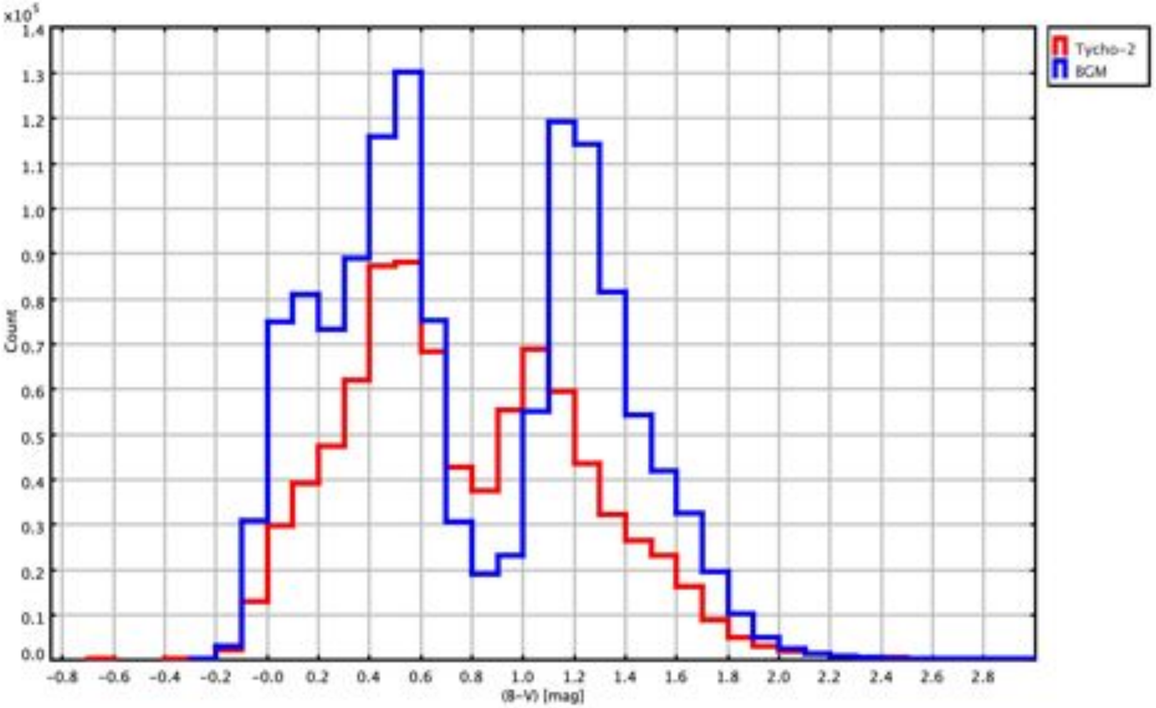


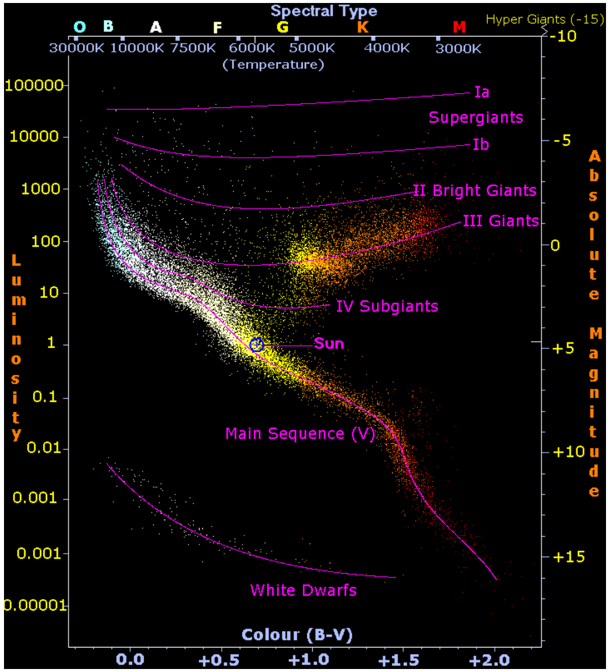


Proper motion in longitude ~ 0.1 of difference, however with caution!

OUR FUNDAMENTAL PROBLEM we met while working with Tycho-2

BGM vs. Tycho-2 B-V distribution





Cumulative all sky histograms, but the same tendencies are present in every single field analysis.

Three main discrepancies we have to deal with are:

1) **The shift of the red peak** when comparing model and data ~**0.2** mag.

2) The proportion of number of objects in each peak between model and data.

3) **The difference in the total number of objects.**

The list of possible scenarios which could be responsible for what we see in B-V distribution:

- Extinction law
- Photometry transformation
- Binarity
- Evolutionary tracks
- IMF & SFR.
- age – metallicity distribution (Haywood, M. 2006)
- Teff, log g, metallicity ⟶ B-V

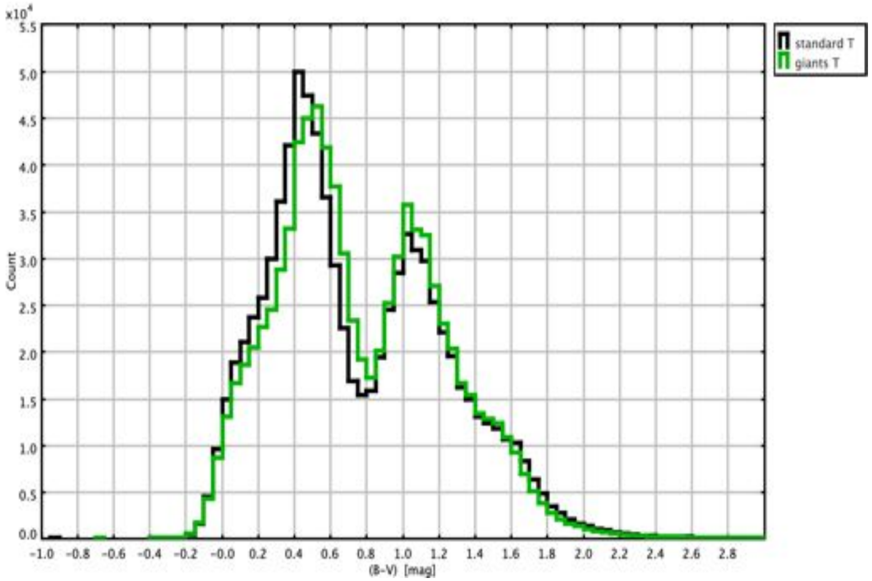
1. Extinction model independent.

Simulations done using: 0.7 mag/kpc, **Drimmel & Spergel (2001)** and **Marshall et al. (2006)** models.

Discrepancies in color distribution discussed before are present when using all three models.

Discrepancies are present as well in the direction of Galactic Poles.

2. Photometry transformation.
Tycho photometry system to Johnson-Cousin



Three methods of photometry transformation were applied and compared.
Small differences can be seen, however they do not explain our discrepancies.

No significant differences can be noticed.

Standard photometric transformation is linear, thus conversion from J-C to Tycho-2 would neither change the distribution shape.

Vol.1 Hipparcos and Tycho Catalogues (Sections 1.3 and 2.2)

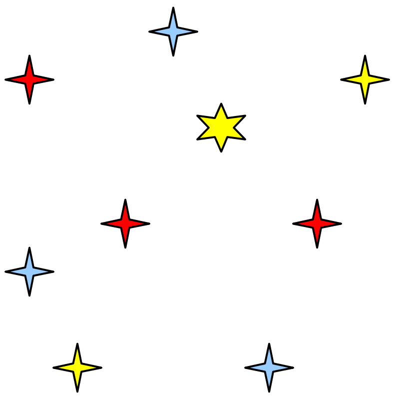
3. Binarity.

single stars color distribution vs. multiple stars color distribution

The shift of the red peak could be caused by the fact that the BGM produces only <u>individual stars</u> !? while in the real data there must be many <u>multiple systems</u>.

Given a single star set transform a factor of stars into doubles.

Specifying binarity rate: 30%, 50% or 70%, ...
and angular separation limit of the catalogue



Split the sample across 10 age boxes (BGM).

a random drawing according to the binarity rate:

double

- not a companion of some other
- there is a neighbor which is:
-     * a double star
-     * the same age
-     * not a companion of another
- IF Yes – double system

single

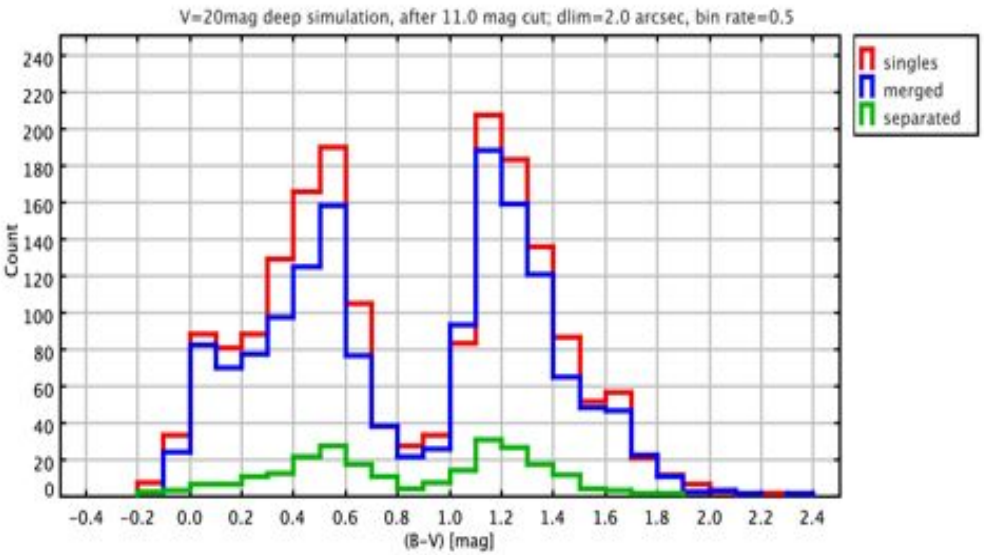
IF Not

The separation value is drawn from a Gaussian distribution + a priori knowledge;
Together with distance it gives the separation angle;
And together with the inclination of the system gives the projection of the stars separation on the sky.

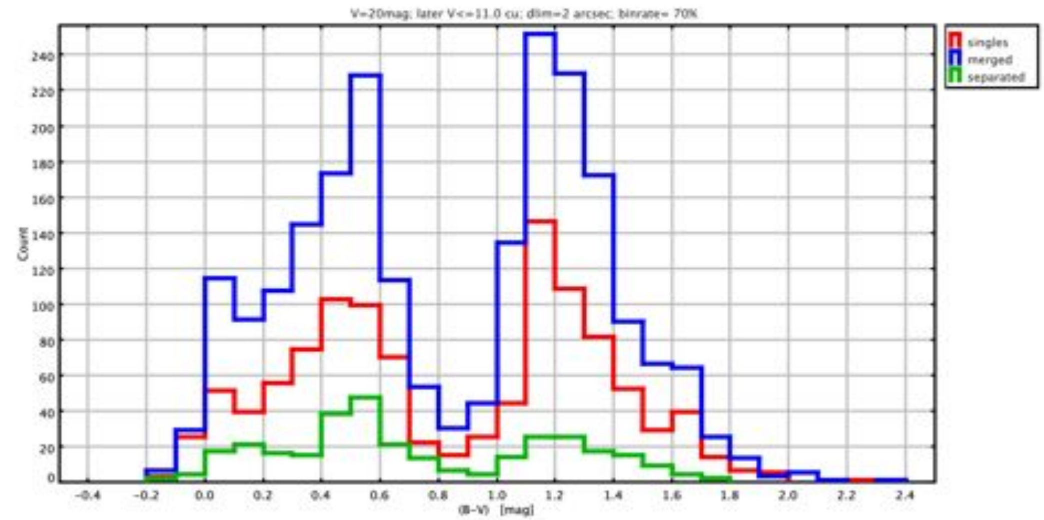
Doubles merged or separated.

3. Binarity. Our tests.

Binarity rate and angular separation limit.



1. (50% and 2 arcsec)



2. (70% and 2 arcsec)

Changing the separation limit would change the proportion between merged and separated stars. **Separated double have the same (B-V) distribution as singles!**
Changing the binarity rate changes the star counts of each three groups of stars.

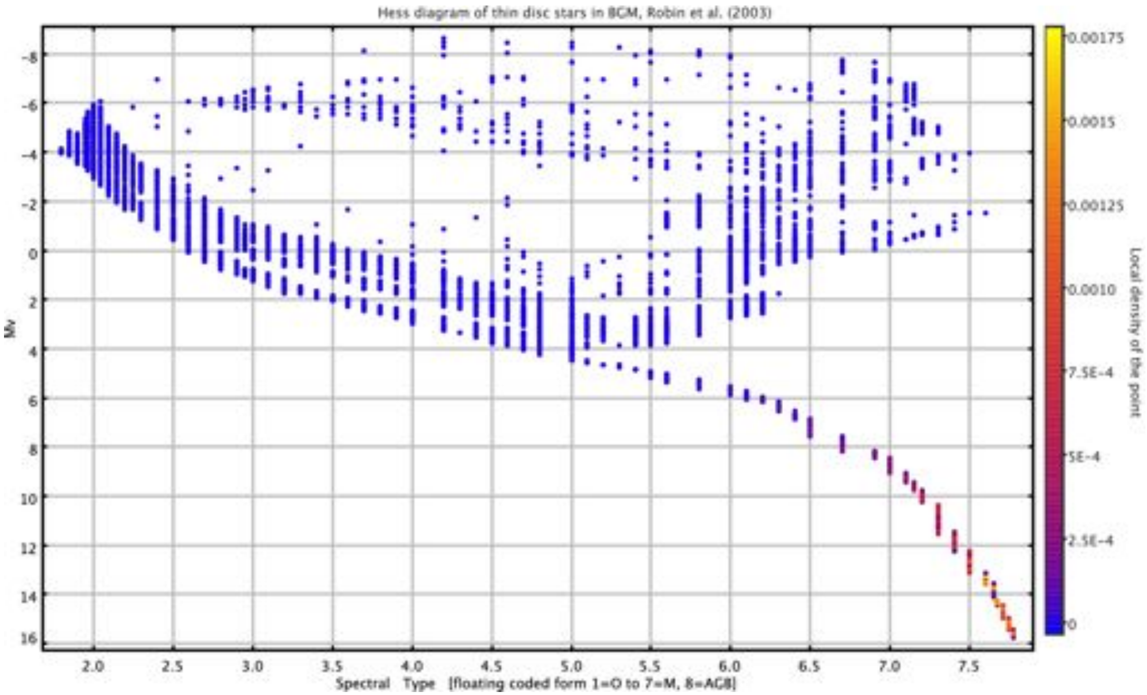
None of this two parameters has an impact on the peaks positions in the (B-V) distribution.

The list of possible scenarios which could be responsible for what we see in B-V distribution:

- Extinction law
- Photometry transformation
- Binarity
- Evolutionary tracks
- IMF & SFR.

At present a particular IMF, SFR and evolutionary tracks are frozen inside the BGM without a possibility to modify them.

- age – metallicity distribution (Haywood, M. 2006)
- Teff, log g, metallicity ⟶ B-V



Hess diagrams for each model population were calculated assuming a given IMF, SFR and using particular set of evolutionary tracks.

It is like a t**hree dimensional HR diagram**, where every point (Mv; Spectral type) is associated with a density of stars existing there (stars/pc^3) and also with the age distribution (7 factors corresponding to 7 subcomponents).

THIN DISC

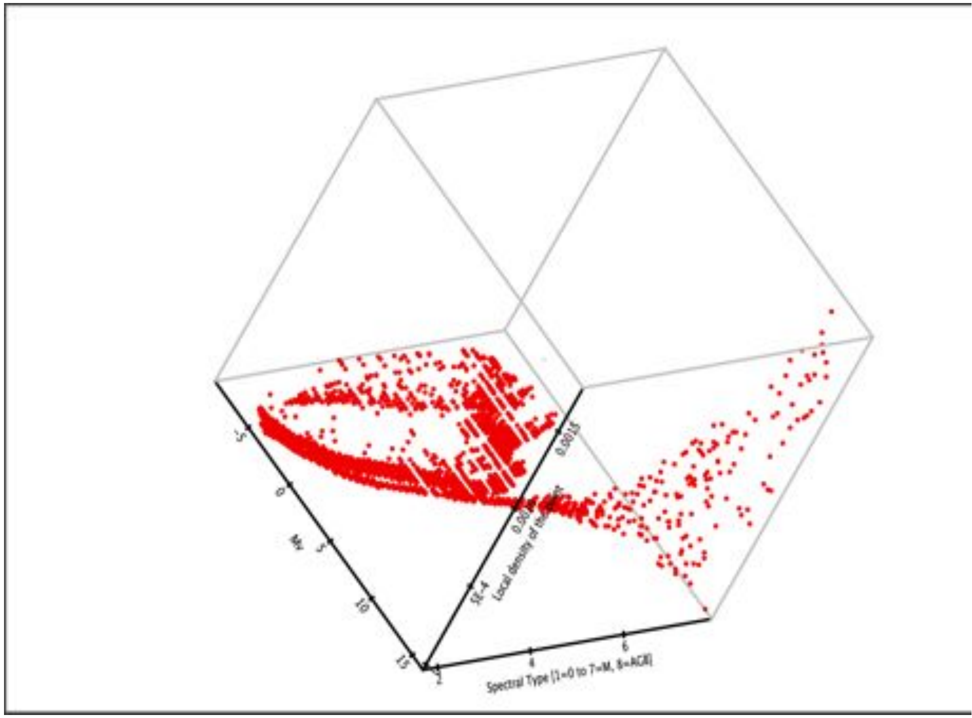
SFR – constant

IMF – power-law with 3 different slopes on 3 mass intervals: x = 0.6 (0.11; 0.2 Msun), 0.6 (0.2; 1 Msun), 2 (>1Msun)

Tracks: Masses >1 Msun Schaller et al. (1992), Low masses from Vandenberg (private comunication), Helium-burning stars at masses between 1 and 1.7M from Castellani et al. (1992)

Integration time: 10 Gyr

M. Haywood et al. 1996



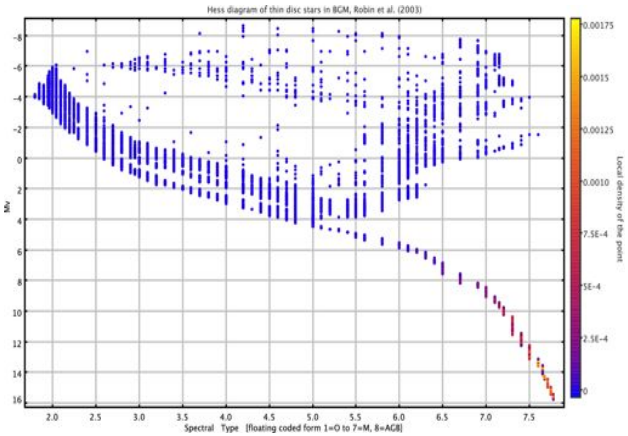
Besançon Galaxy Model

– turning the **IMF**, **SFR** and **evolutionary tracks** into **free user specified parameters.**

This coding task is actually an important change in star production philosophy.

Present stars production

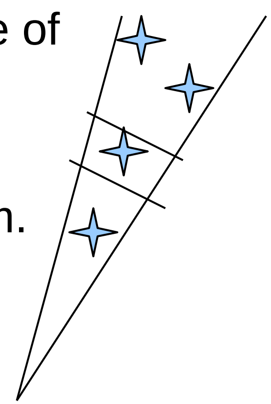
fixed Hess diagram



For all volume elements on the line of sight,

for each population separately,

summation on whole Hess diagram.



flexible pieces of code

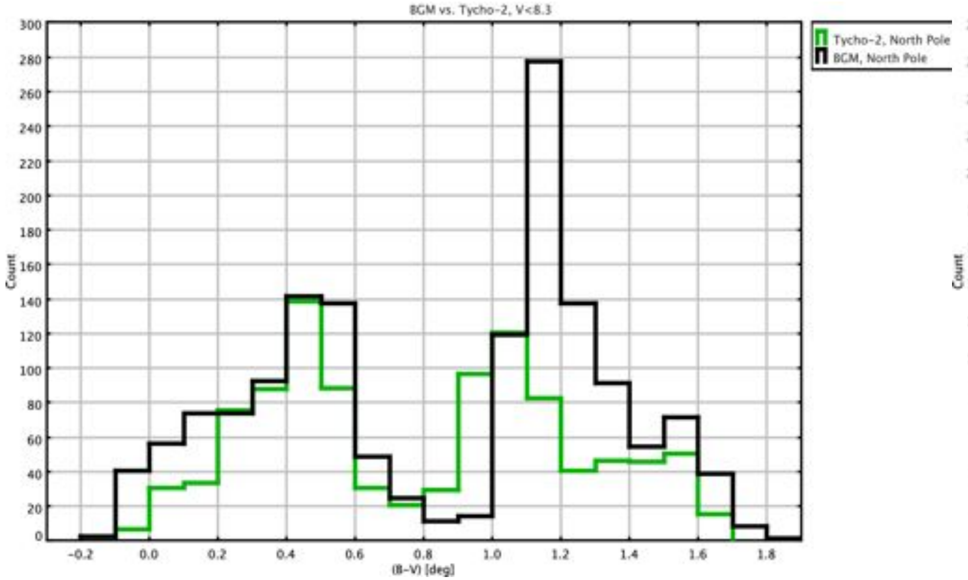
IMF SFR evolutionary tracks

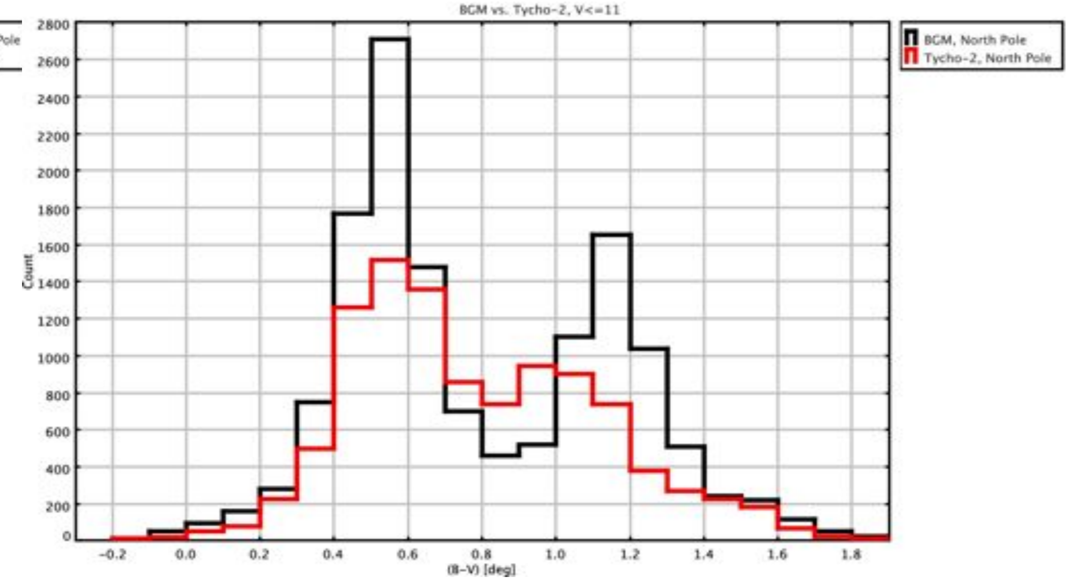
reading input data

In a volume element:

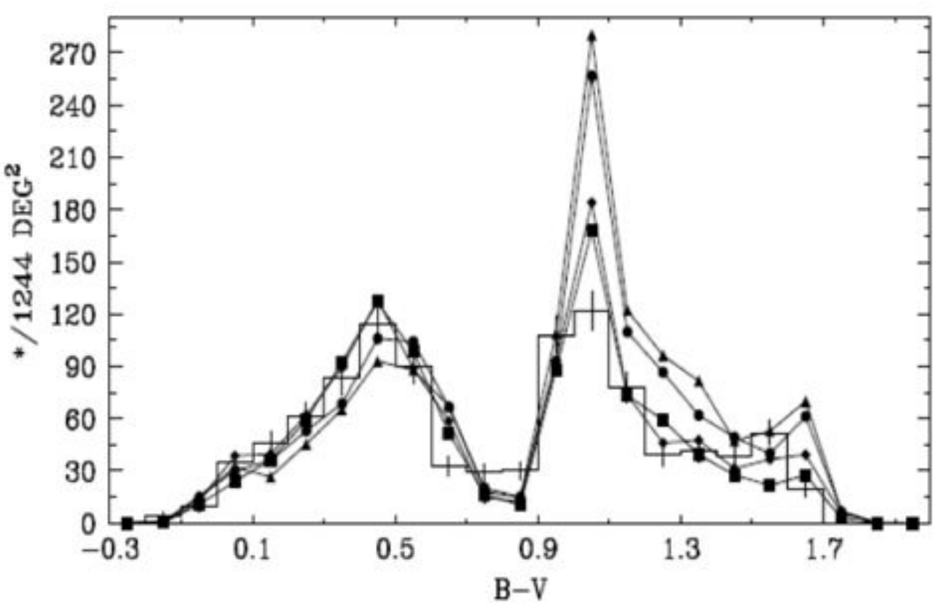
- calculate **the total mass reservoir** according to the density laws (parameters + gradients) +**SFR**
- generate star by star until there is **mass available, mass reservoir > 0**
- The mass of each individual star is being drawn according to the shape of **IMF**
- when age, mass and metallicity of a star are known we find its position (Teff, log(g), Luminosity) on HR diagram from **evolutionary tracks.**

Tycho-2 vs. BGM, Galactic North Pole, V<8.3 and V<11.0

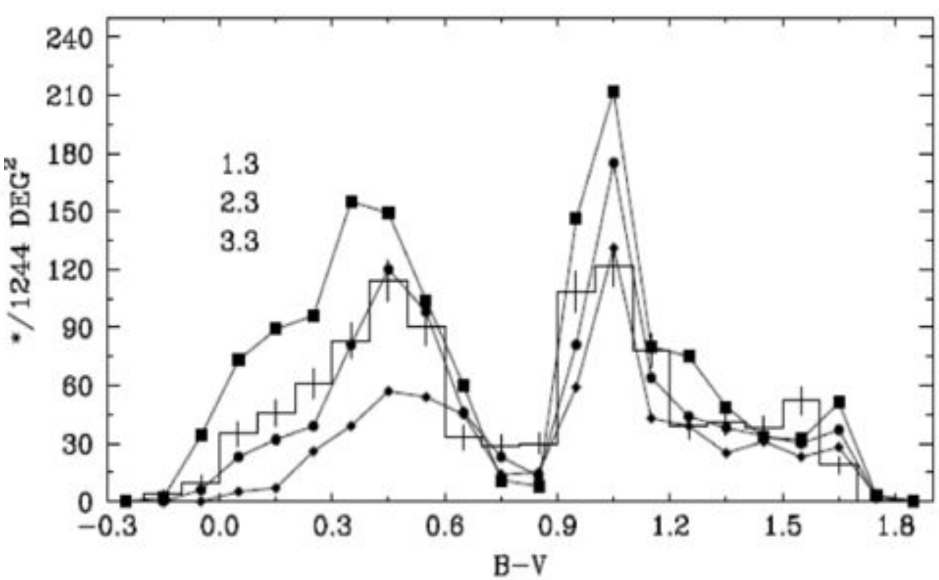




M. Haywood et al. 1997; INCA stars with V < 8.3, different SFR and IMF scenarios



Squares - increasing SFR, diamonds - constant, Circles and triangles for decreasing SFR with amplitudes 3.5 and 7 respectively.



SFR-constant, 3 different slopes of the IMF in the mass range from 1 to 3 solar masses.

Steps we will follow:

1. Primary test: perform simulations imposing the same IMF and SFR and compare old/new simulations with the Tycho data.

2. Change the IMF and SFR taking care about the dynamical self-consistency of the model (Bienayme et al., 1987).

3. Implement binarity.

4. Kinematics analysis (Tycho-2, Rave, ...)

Thank you.