# Modelling the evolution of the Milky Way from Gaia DR3

A.C. Robin, M. del Alcázar, C. Figueras, O. Bienaymé

# Elements to constrain the evolution of the Milky Way

Ages not obvious to determine, stellar model dependent, large uncertainties and for very limited samples => more an uncalibrated scale than real ages

Age indicators : even less accurate but are available for much larger samples, and are interesting to indirectly follow the evolution (statistically)

- chemical abundances

- dynamics

- spectral types / stellar evolution stages

The combination of those gives more constraints on Galactic evolution

- Beatrice Tinsley : simple characterisation of galaxy evolution : function of star masses and time
- Assume independent
- Initial Mass Function (IMF) and Star Formation History (SFR), basic functions to model galaxy evolution
- Population synthesis : assumes IMF and SFH, produce simulations and compare with data (statistics)

*Ilustración de Beatrice Tinsley por Pelopantón*

# Population synthesis in the Besançon Galaxy Model (BGM)

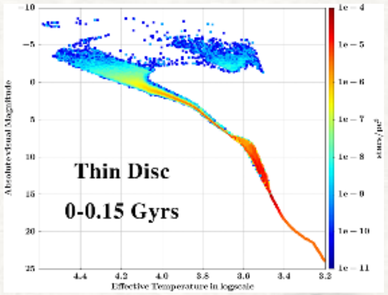
Simulation of stars, with their characteristics and their sky distribution

STARS GENERATED THROUGH IMF, SFR AND EVOLUTIONARY TRACKS

*(Robin & Crézé, 1986, Haywood et al, 1996, Czekaj et al, 2014, Lagarde et al 2017, 2018, Mor et al 2018, 2019, etc.)*

ρ(x,y,z) : density laws constrained by Dynamics

*(Bienaymé et al, 1987, 2015, 2018)*




3D extinction
+ Observational errors

Simulated catalogue: photometry, astrometry (pm, Vlos, parallax), Teff, log, [M/H], [alpha/M]…

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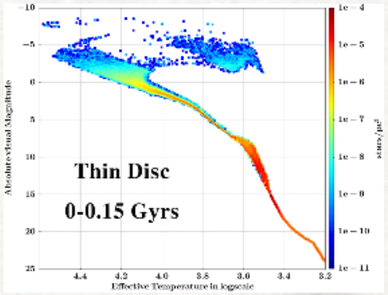


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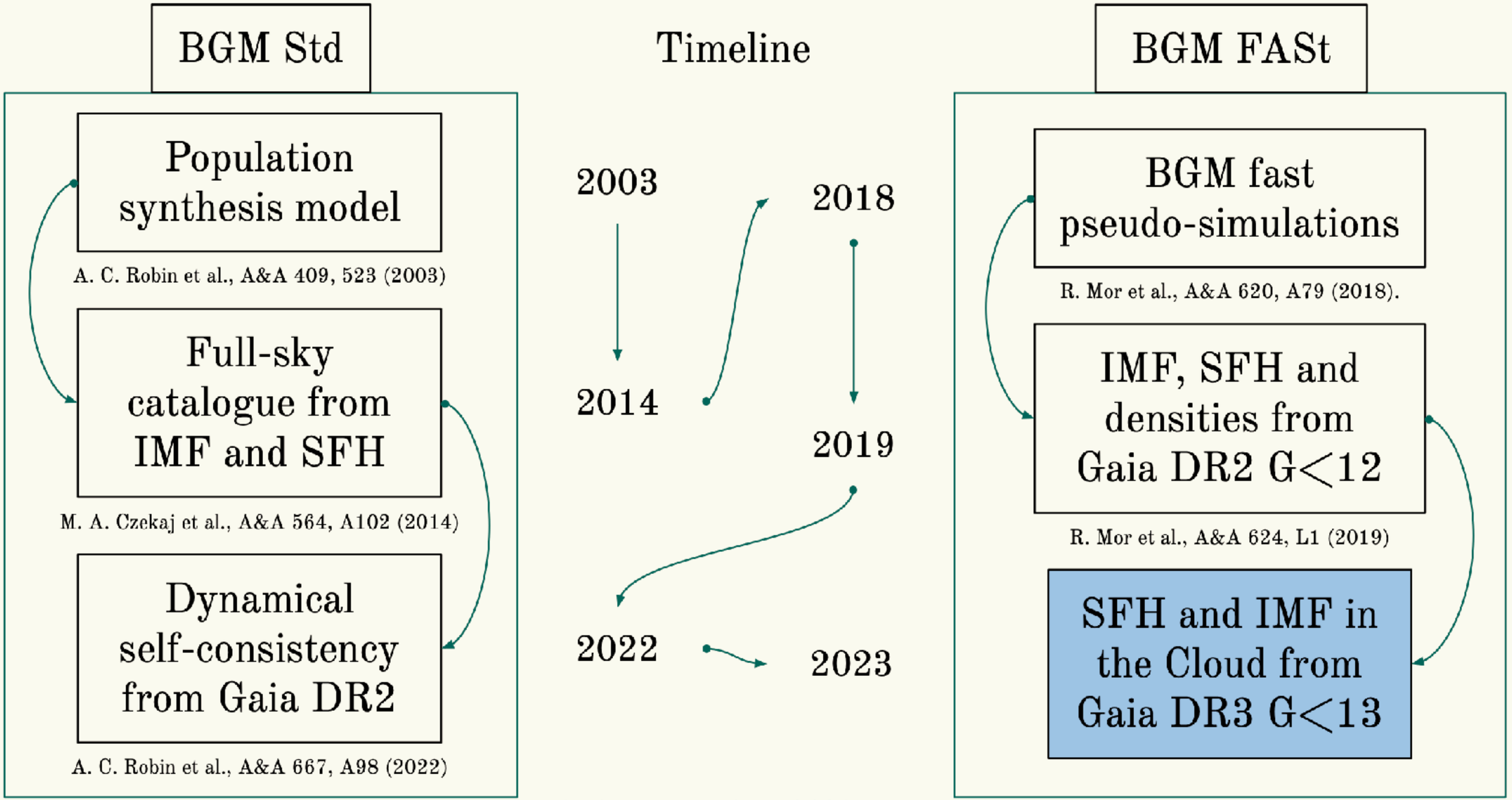
# Dynamics and constraints on IMF and SFH




*Del Alcázar i Julià (2023) Master thesis, see poster*

*Bienaymé, Robin & Crézé, 1987 : Boltzmann & Poisson Eq. => density laws for stars (age)*

Only at $R=R_0$ and vertically

*Bienaymé et al 2015 : next step*

- Approximate the potential in the BGM by a **Stäckel potential**
- => To compute 3rd integral of the motion
- => To derive the density and velocity distribution self-consistently at different positions Rgal, Zgal
- Assume stationarity

*Robin, Bienaymé et al 2022 : Constrained with Gaia DR3*

# ITERATIVE PROCESS

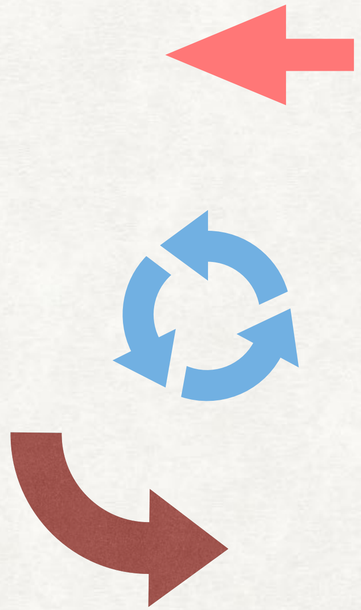
GAIA

F(PARALLAXE)
VTL, VTB QUANTILES

Simulations

fit model with MCMC with a fixed potential, with approximate changes on DFs

MCMC SOLUTION



New DFs

Exact Potential
Constrained By Vcirc

# Quality of the fit

Magenta: local GCNS

Cyan: Deep fields

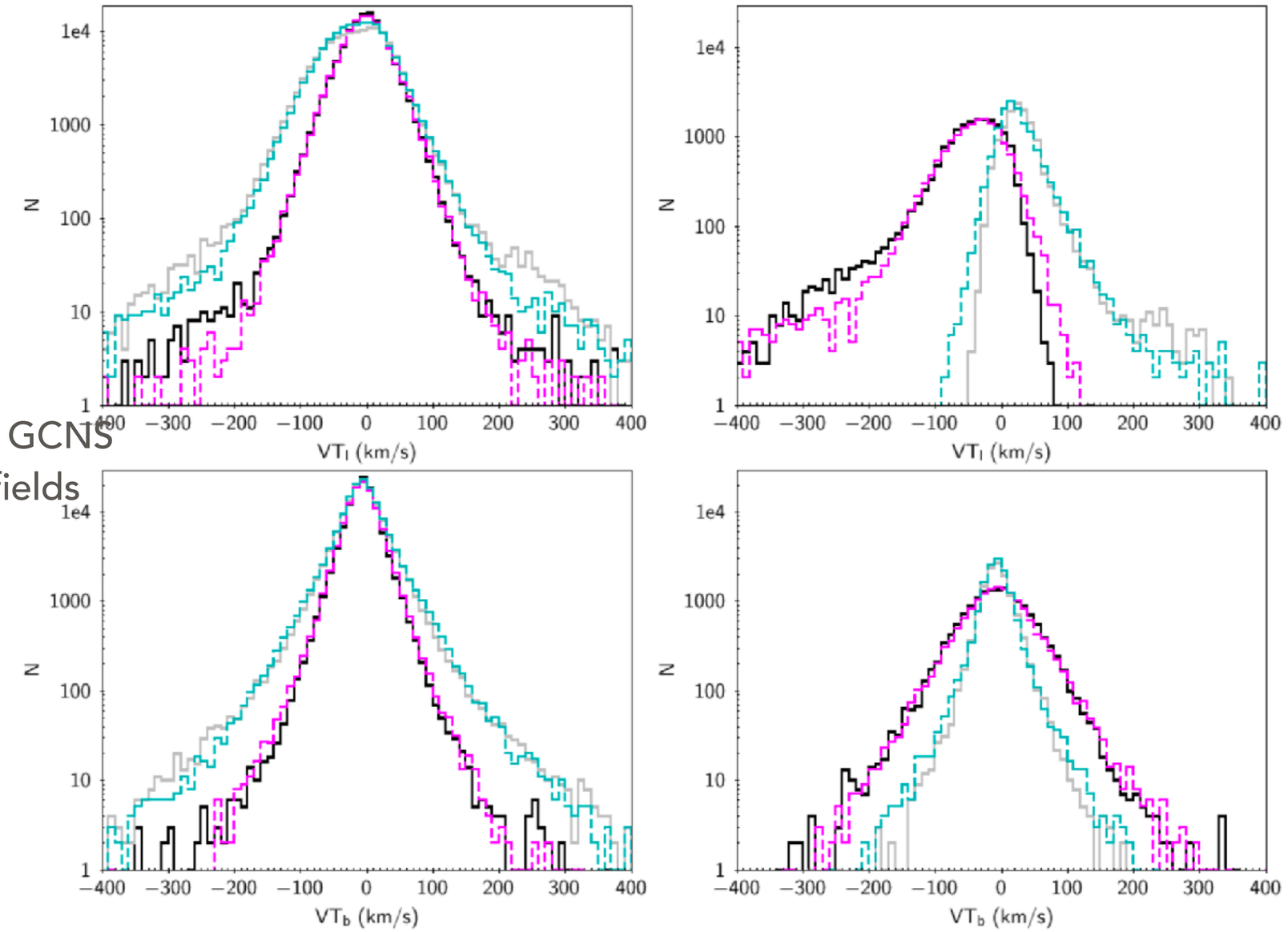
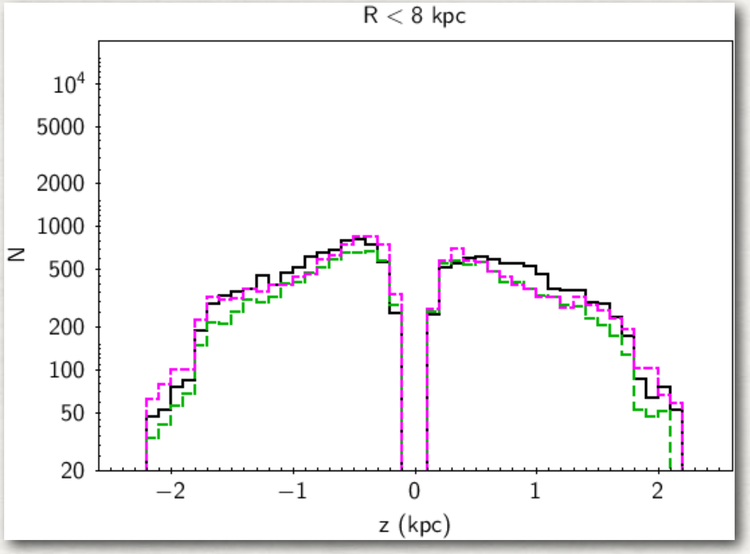
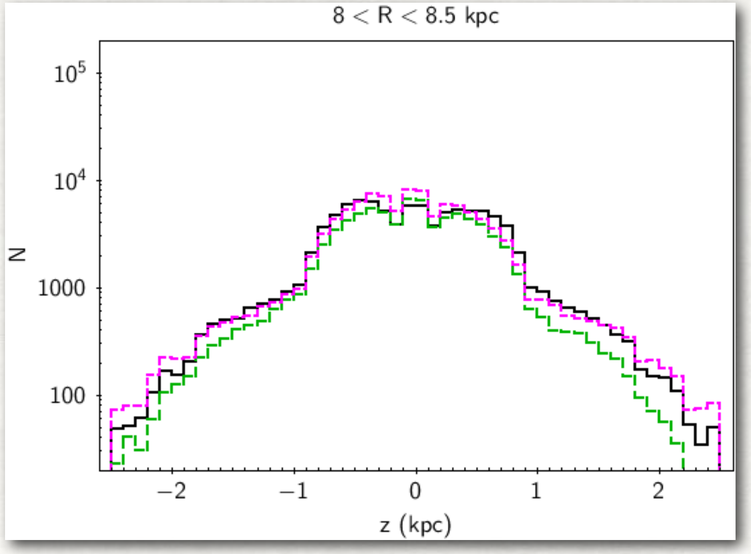


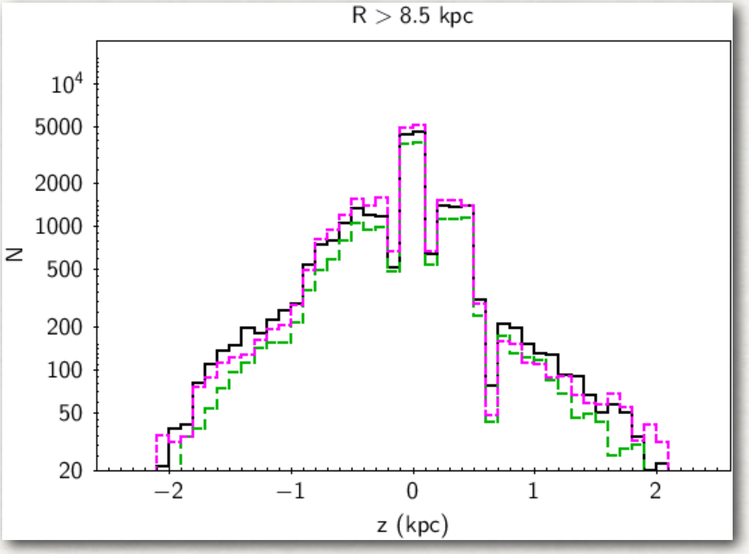

**Fig. 4.** Histograms of the transverse velocities for the local sample and for deep fields, with pseudo-$R$ smaller than 8 kpc or larger than 9 kpc: $Vt_l$ (top row ), $Vt_b$ (bottom row). Left column: local data (continuous black line), local model (magenta dashed line), deep fields data (continuous grey line), deep field model (dashed cyan line). Right column: $R < 8$ kpc data (continuous black line), $R < 8$ kpc model (magenta dashed line), $R > 9$ kpc data (continuous grey line), $R > 9$ kpc model (dashed cyan line).

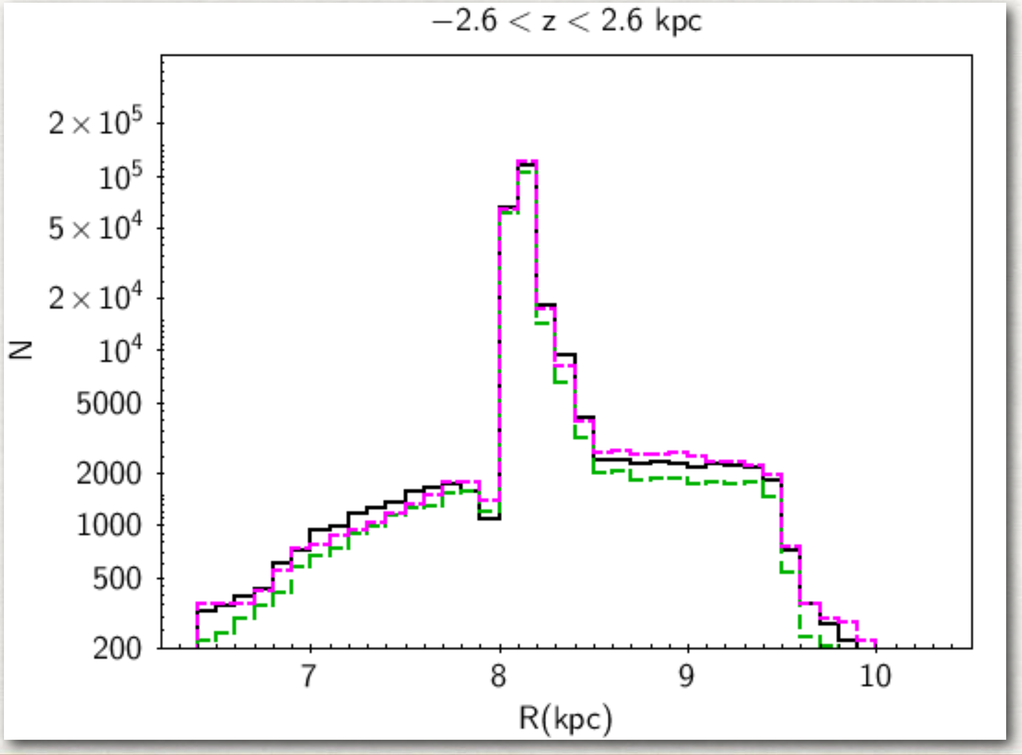
Magenta: R<8 kpc

Cyan: R>9 kpc




Data

Old BGM

New self-consistent model

# Next step

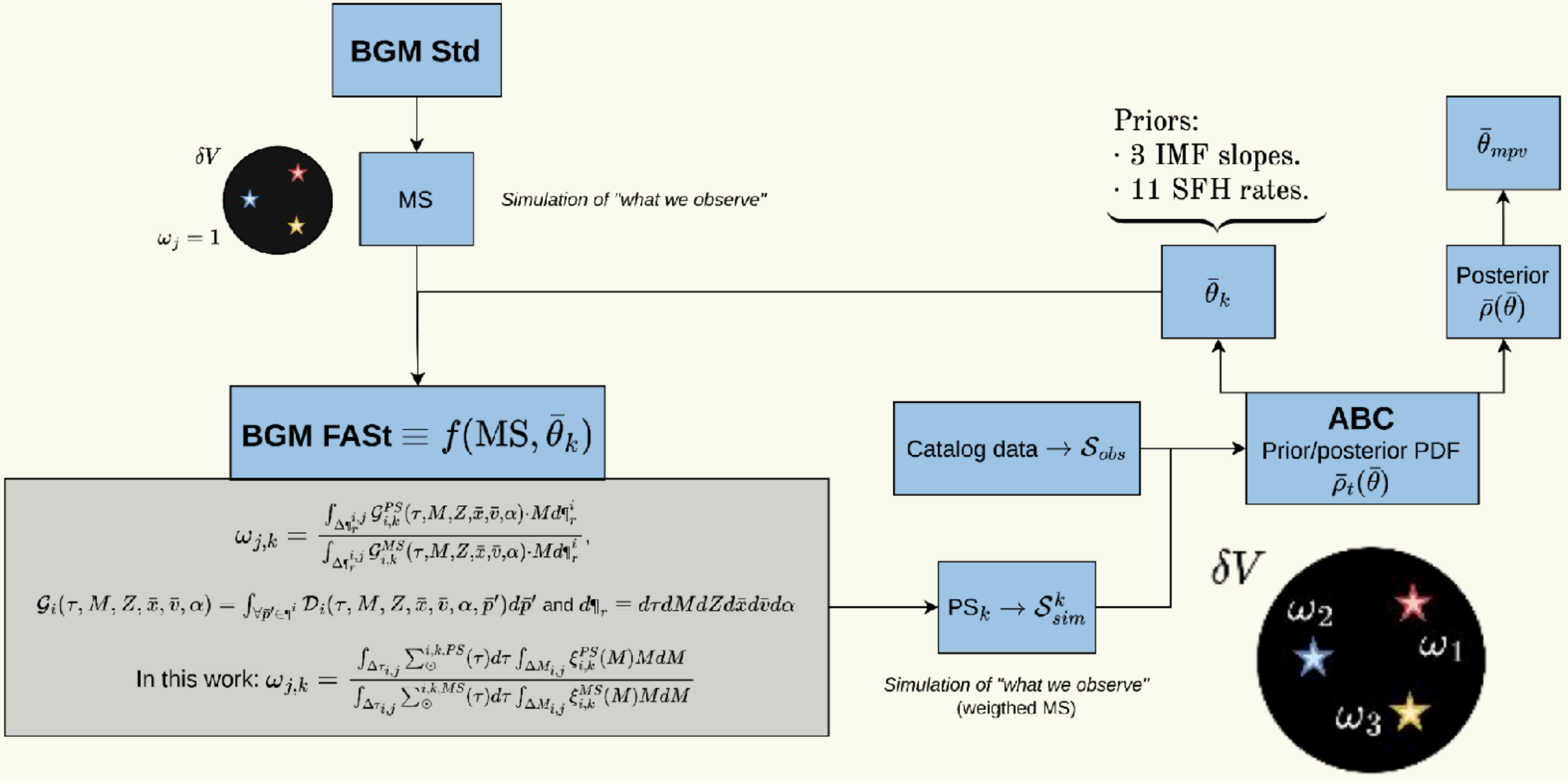
- Dynamics on fixed SFH and IMF (2022).
- Mor et al 2019. ***BGMFASt => new SFH and IMF***

} Loop to get a unique solution

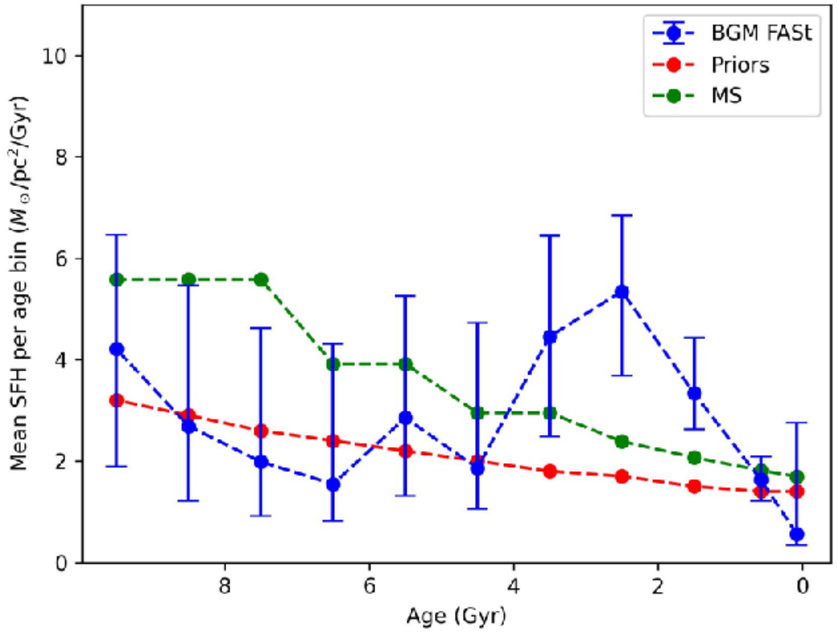
Preliminary results : See del Alcázar i Julià (2023) Master thesis and poster

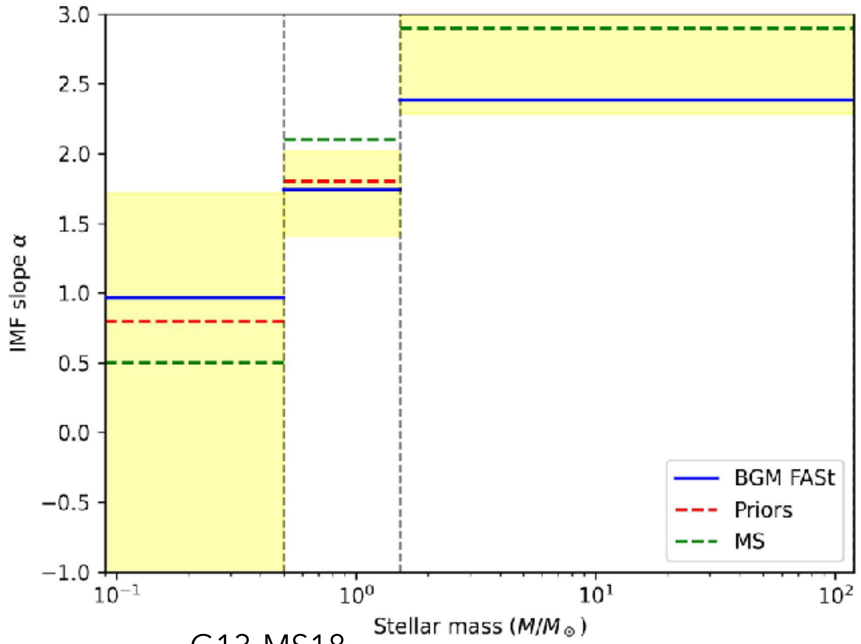
- 1st test: redo BGMFASt runs with new dyn. self-consistent mother simulation.

# The Besançon Galaxy Model Fast Approximate Simulations




R. Mor et al., A&A 620, A79 (2018).




G13-MS18

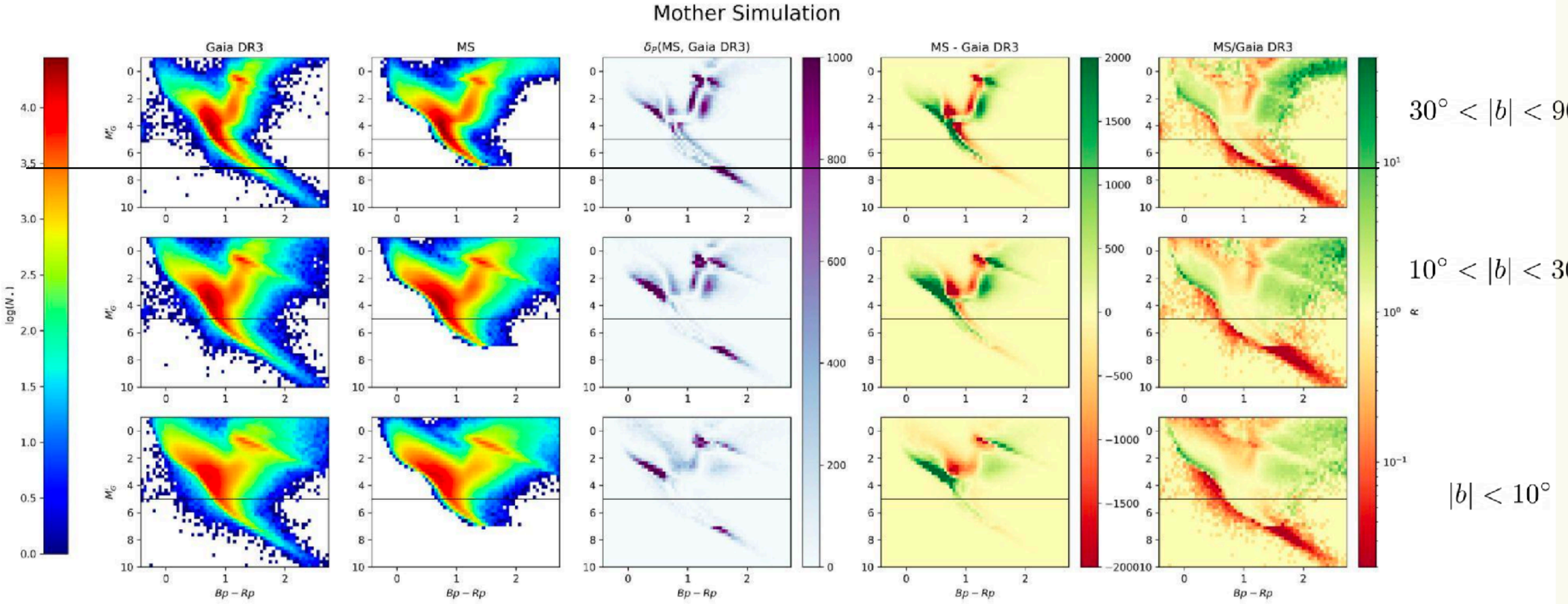
Preliminary results with data G<13:

- Non parametric SFH for the thin disc: confirm the burst at 2.5 Gyr as in Mor+2019
- IMF similar to previous studies
- No constraints on low mass IMF

# Results. Hess diagrams comparison

$$\delta_P(\mathcal{S}_{obs}, \mathcal{S}_{sim}) = \left| \sum_{n=1}^{N_{bins}} q_n[1 - R_n + \ln(R_n)] \right|$$

$$R = \frac{f_n}{q_n},\ f_n = \#_\star^{sim} \text{ and } q_n = \#_\star^{obs}$$




*Del Alcázar i Julià (2023) Master thesis*

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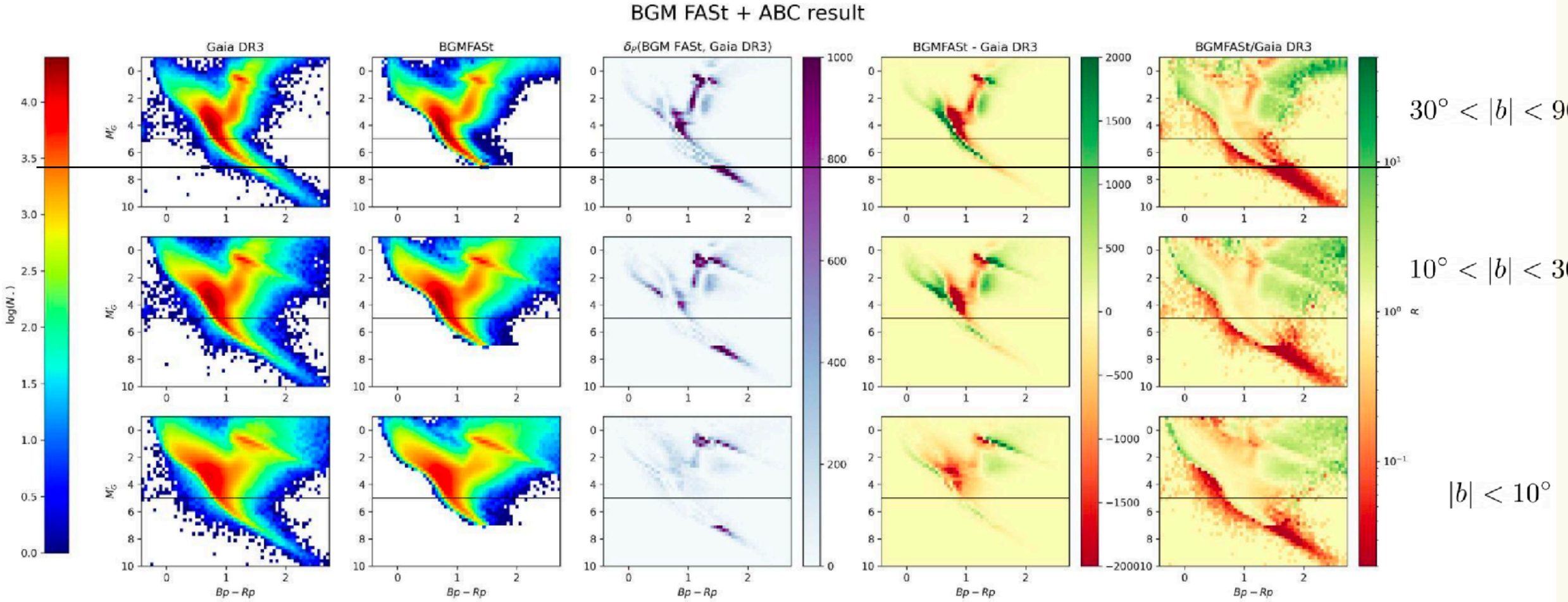
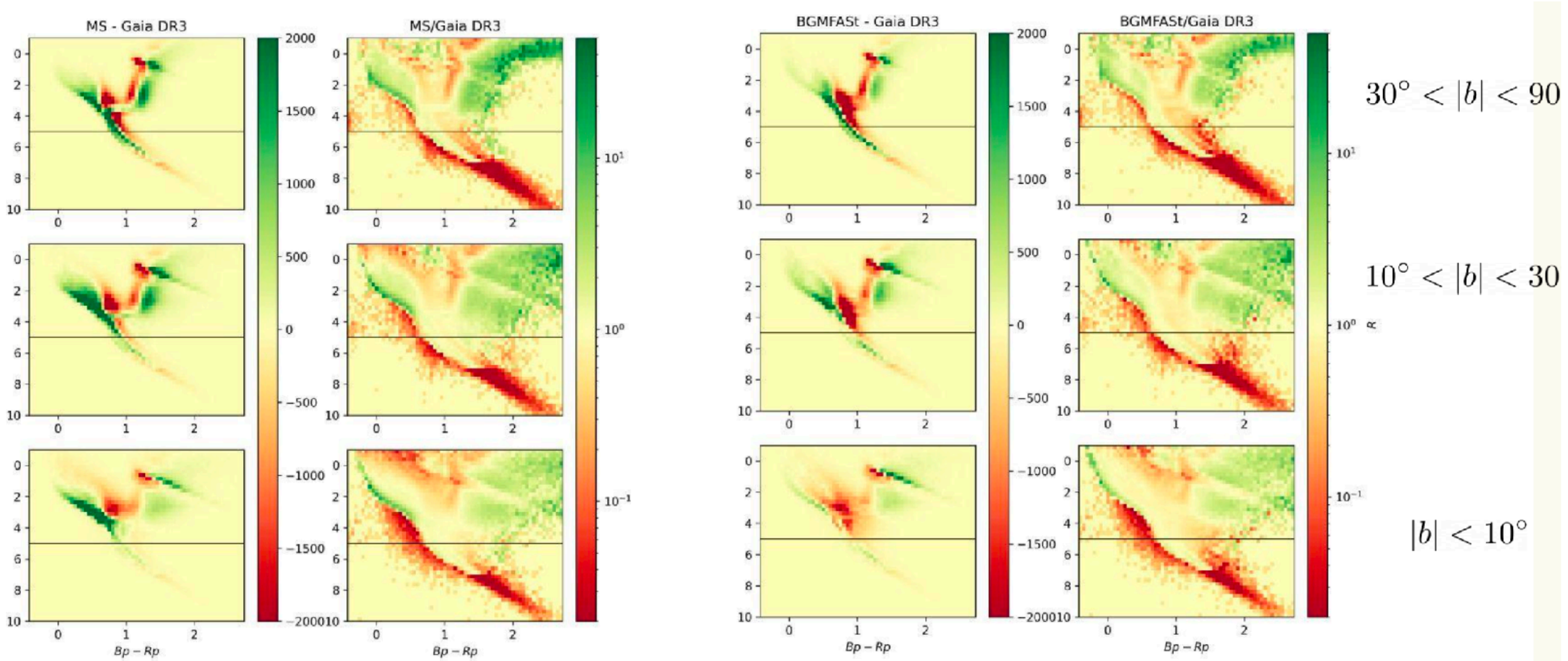



*Del Alcázar i Julià (2023) Master thesis*

Mother simulation

Fit result




=> Better fit to high mass regions and giant branch

Still some progress to do for :

- the position of the giant branch (stellar models atmosphere?)
- the 3D extinction map

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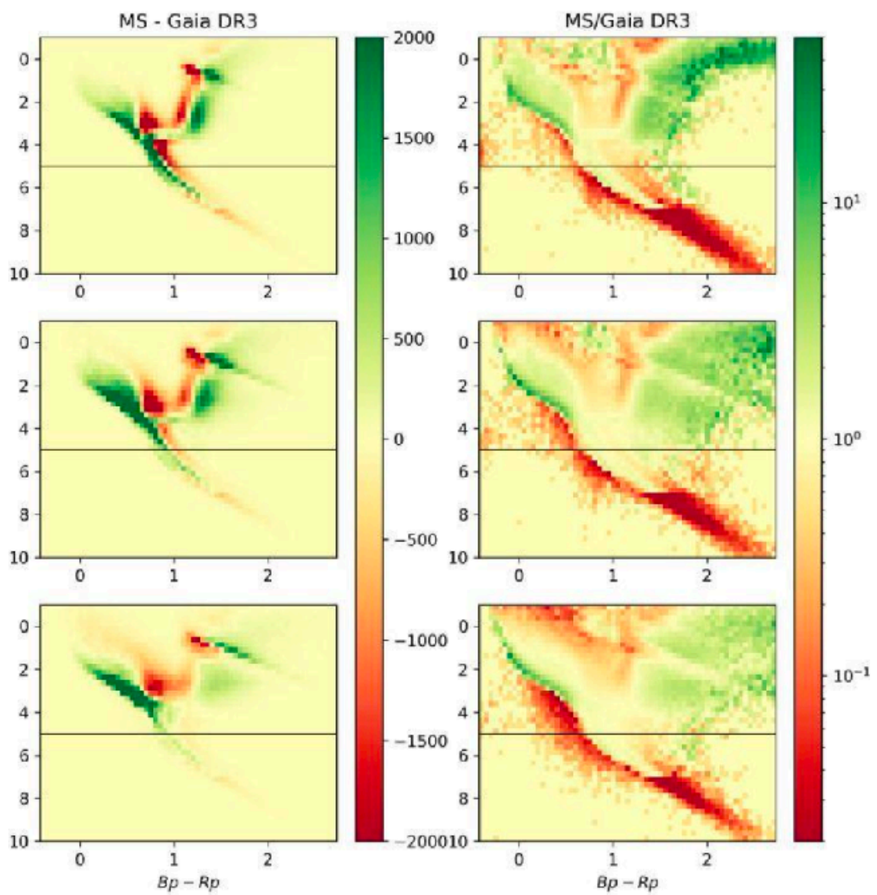


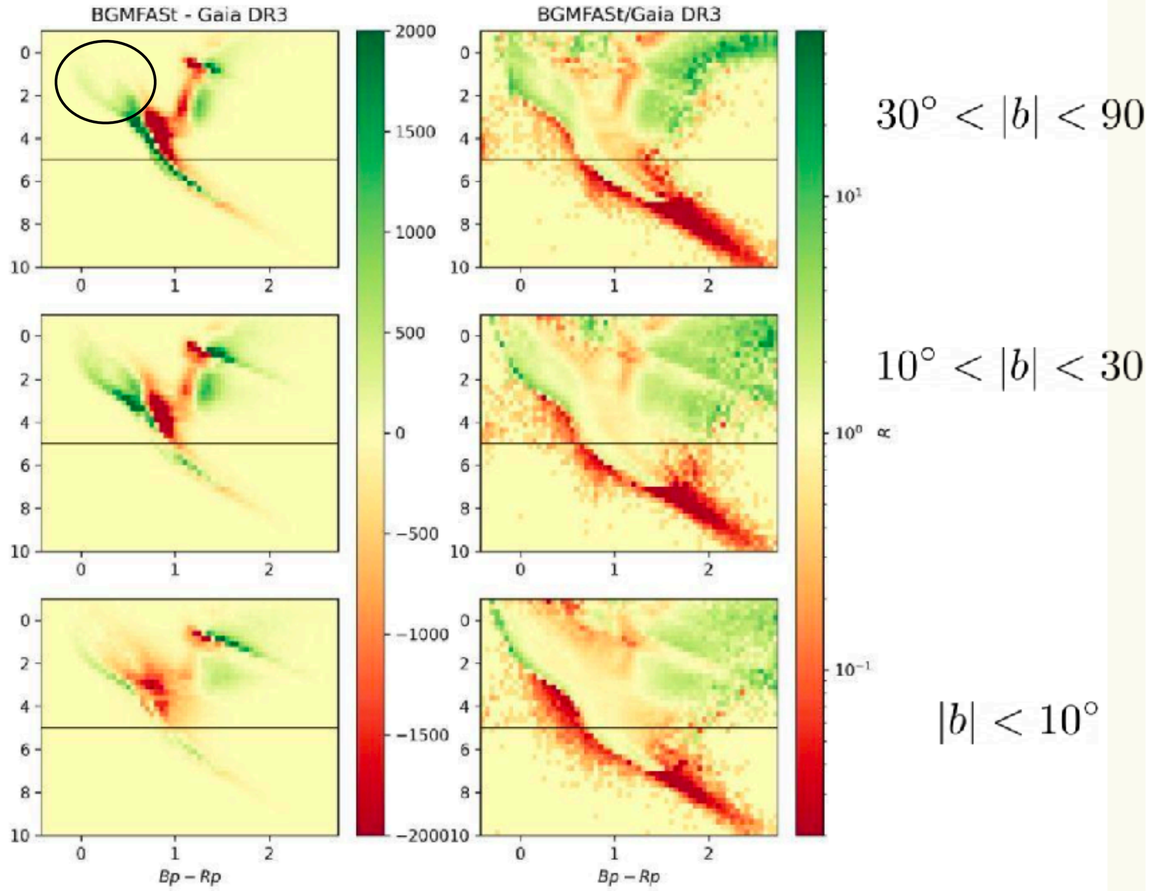


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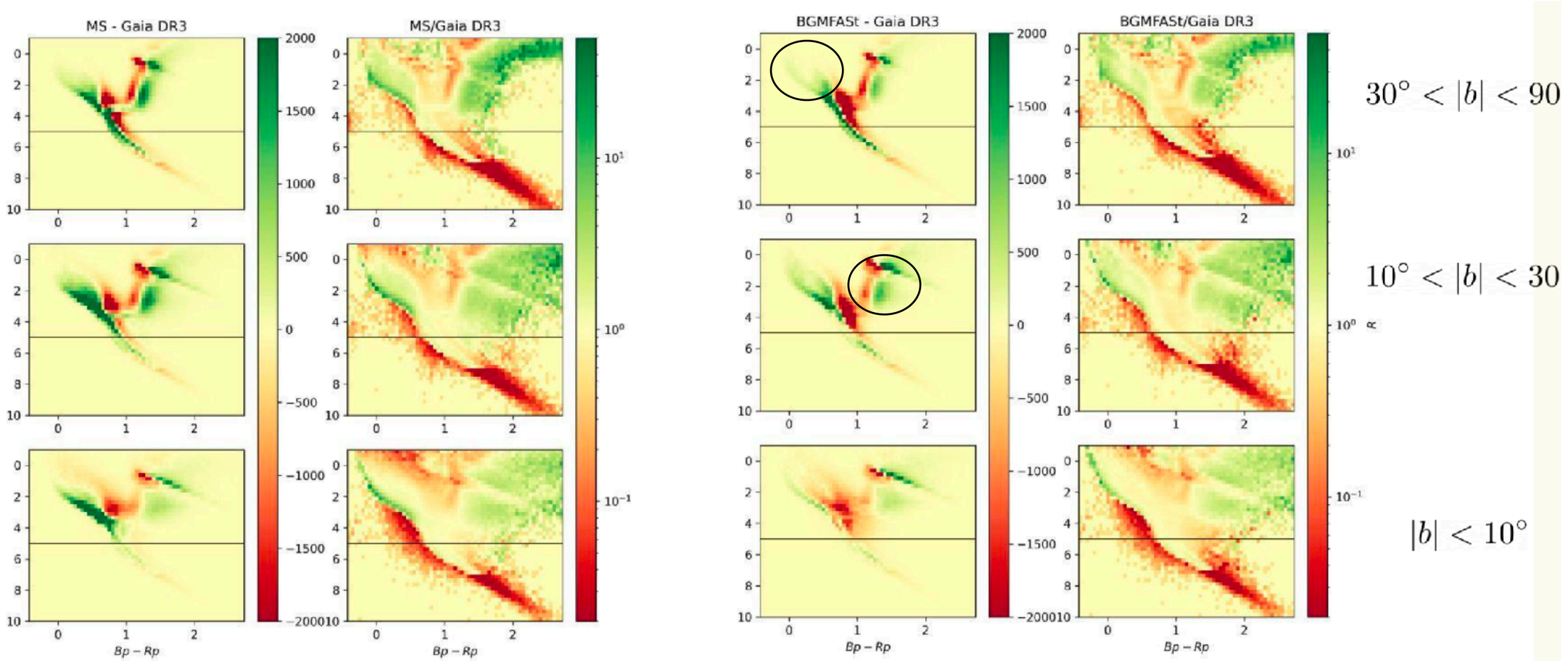


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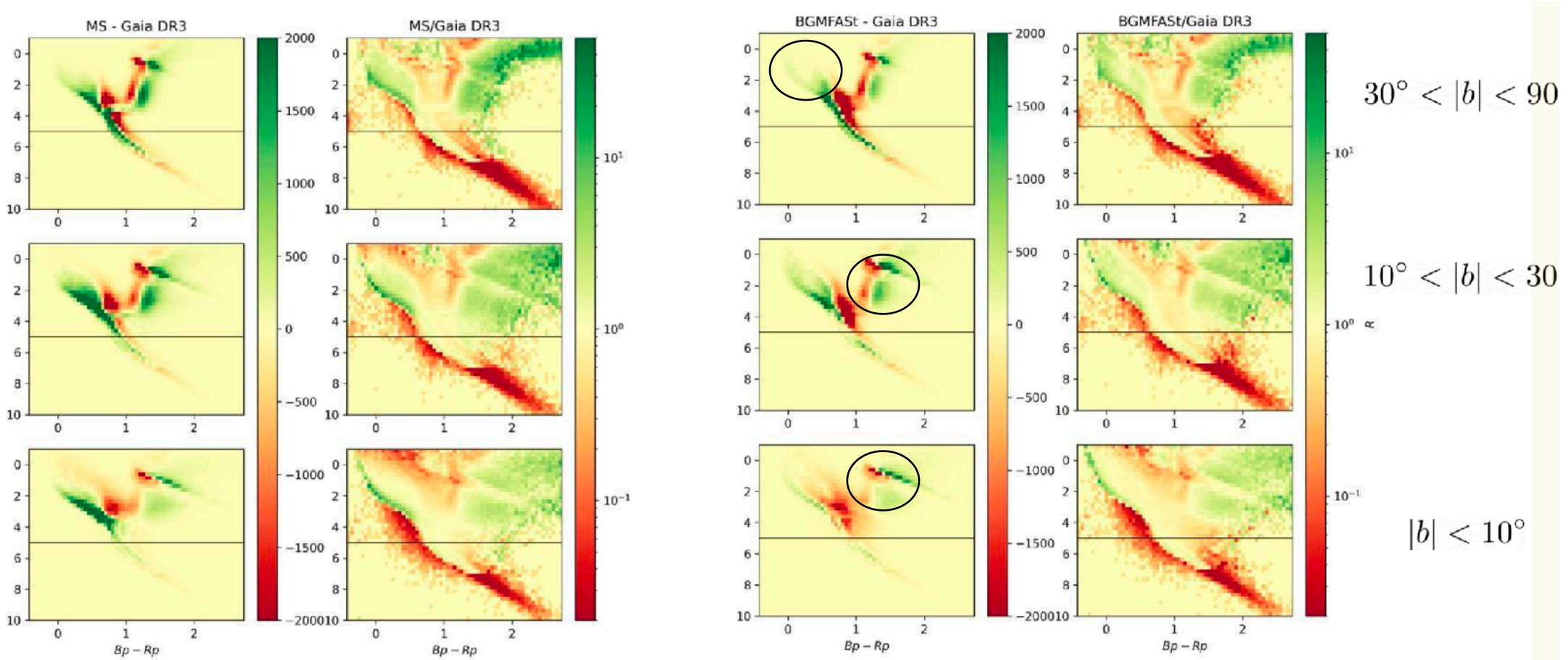


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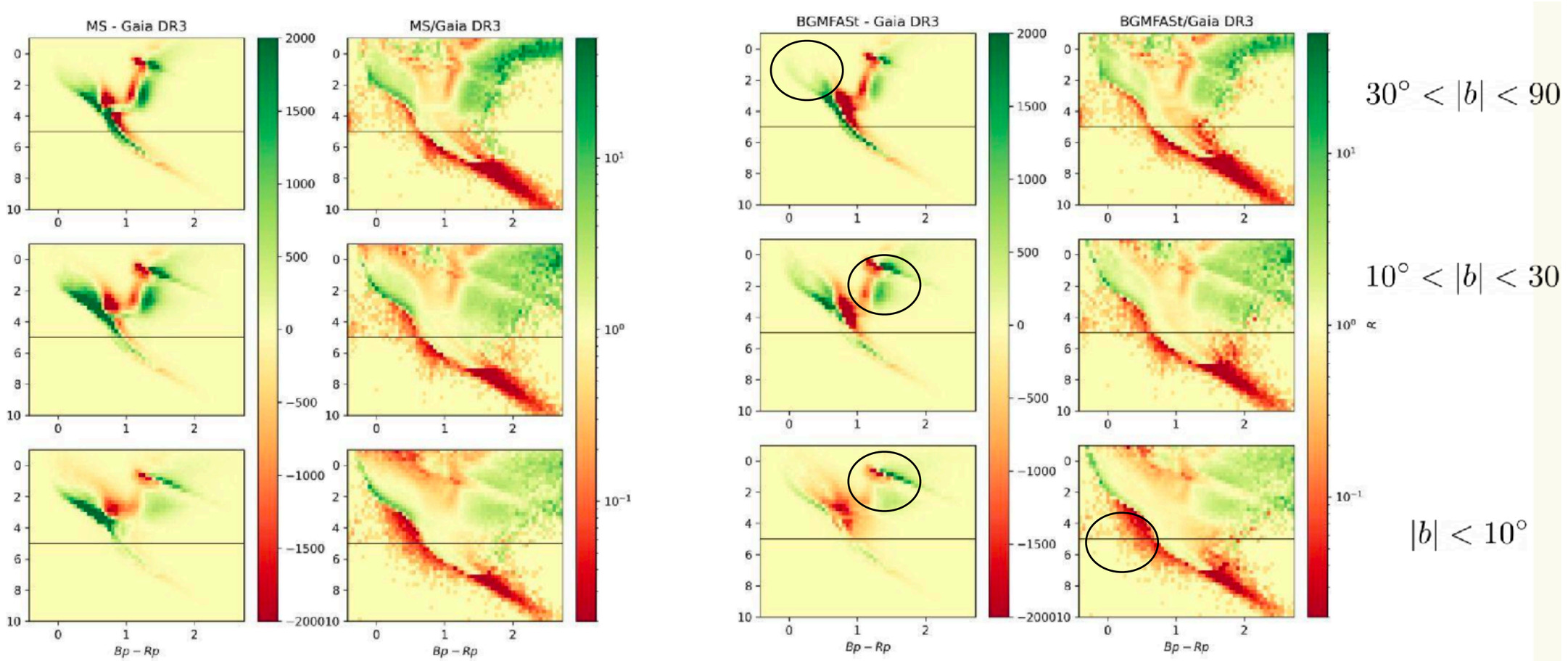


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# Future steps

- Loop between dynamical fitting and SFH/IMF fitting, or create a combined tool to fit IMF/SFH and dynamics all together (ABC or MCMC)

- Need to add further observational constraints to BGMFASt:
  - Constraints from parallax and velocity dispersion distributions (also $V_{los}$)
  - Gaia data still used to G<13 (full sky). Deeper data can be added (on portions of sky)
- Heavy computing facilities needed : Cloud and HPC most useful

*Hoping that a single model  can fit the whole observable distribution… or increase its complexity, adding more science in it*

# Acknowledgments to MW-Gaia COST Action

Thanks for your attention