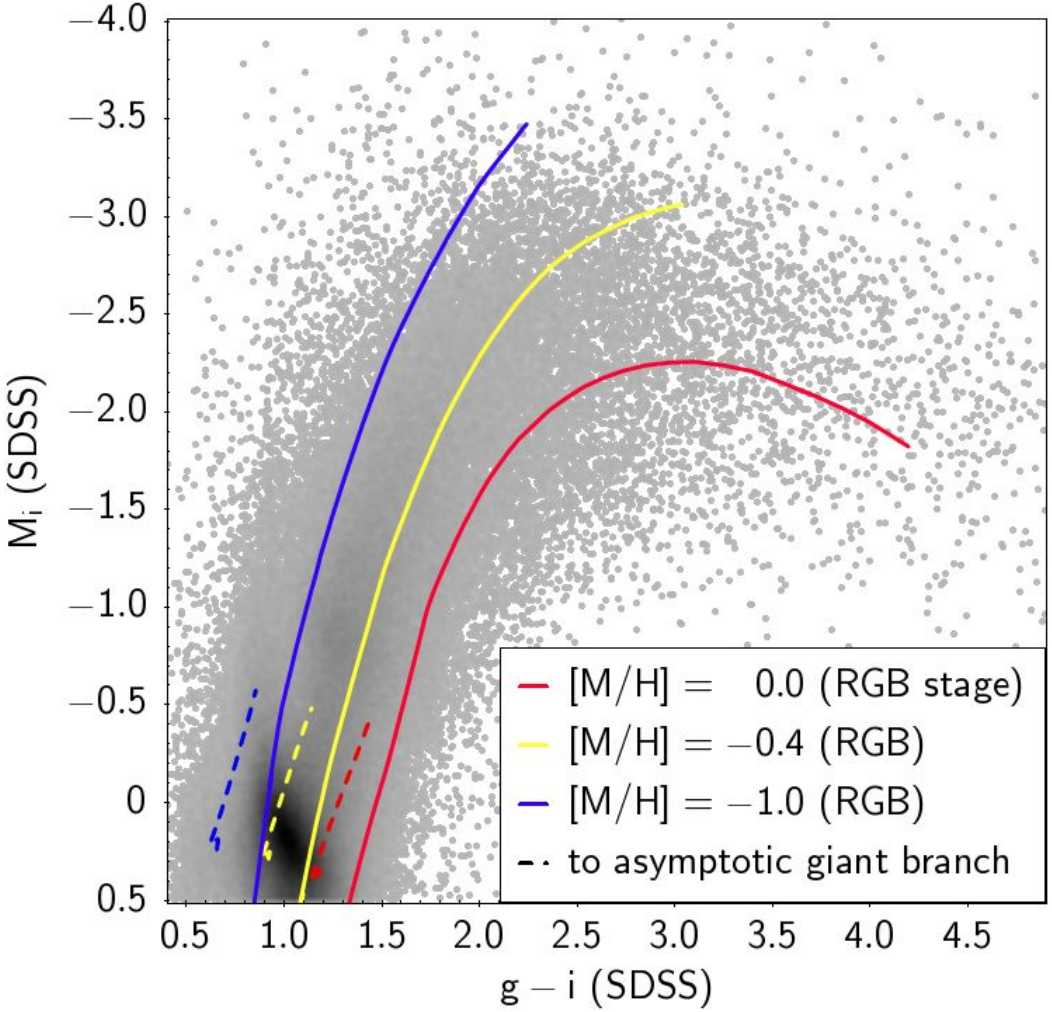
Calibration of the tip of the red giants branch using GAIA DR2

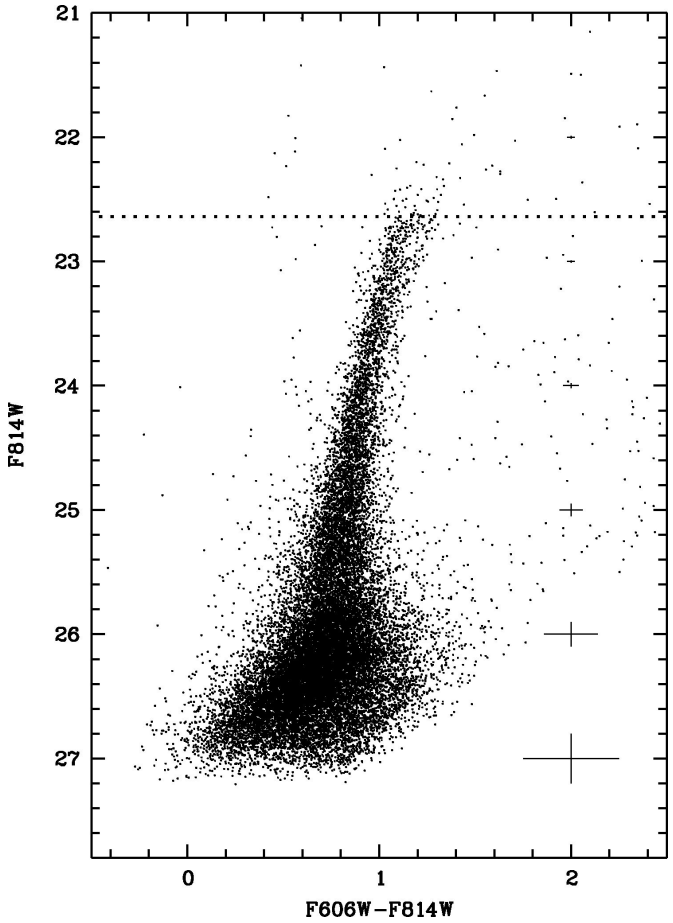
Usachev Pavel, Makarov Dmitry

Tip of the Red Giant Branch (**TRGB**)

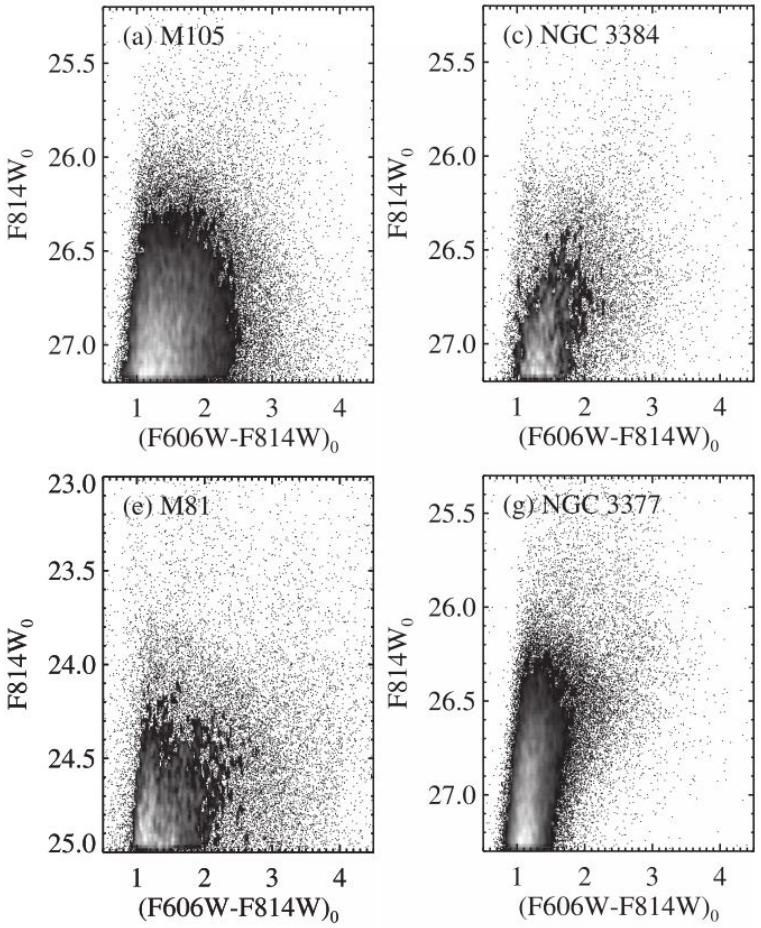
distance definition method

- Method error ~ 0.02 mag
- Theoretically justified
- Bright stars in a galaxy

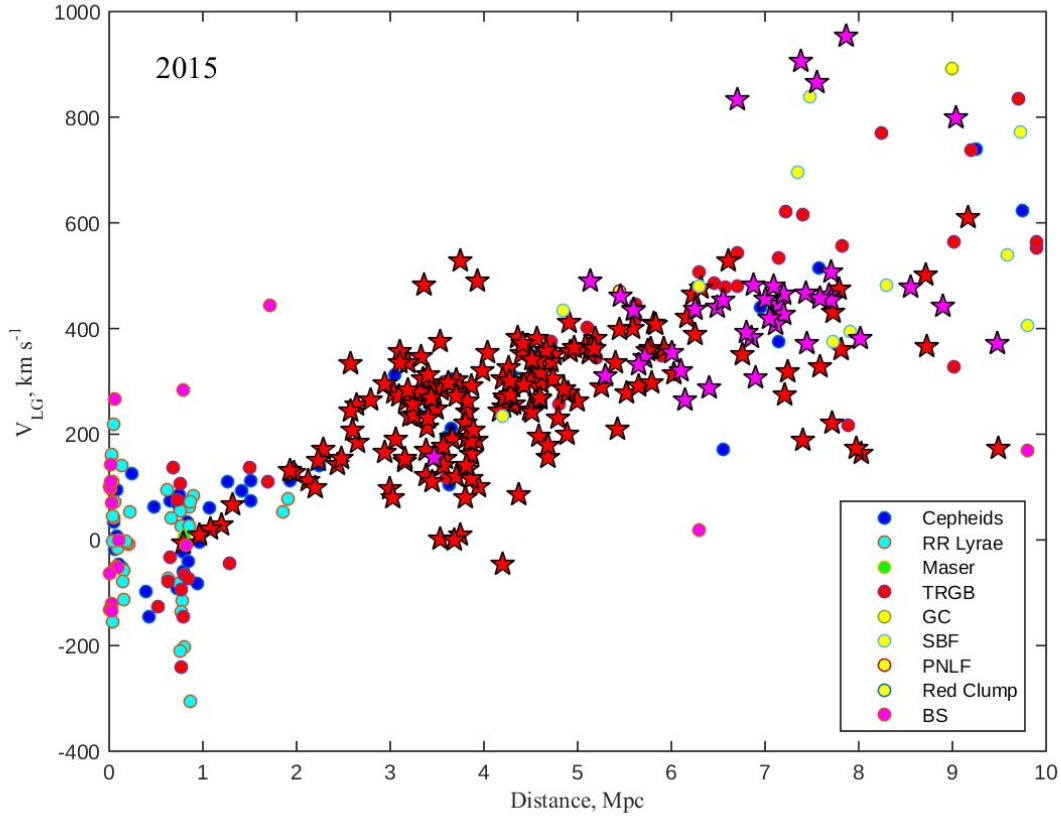




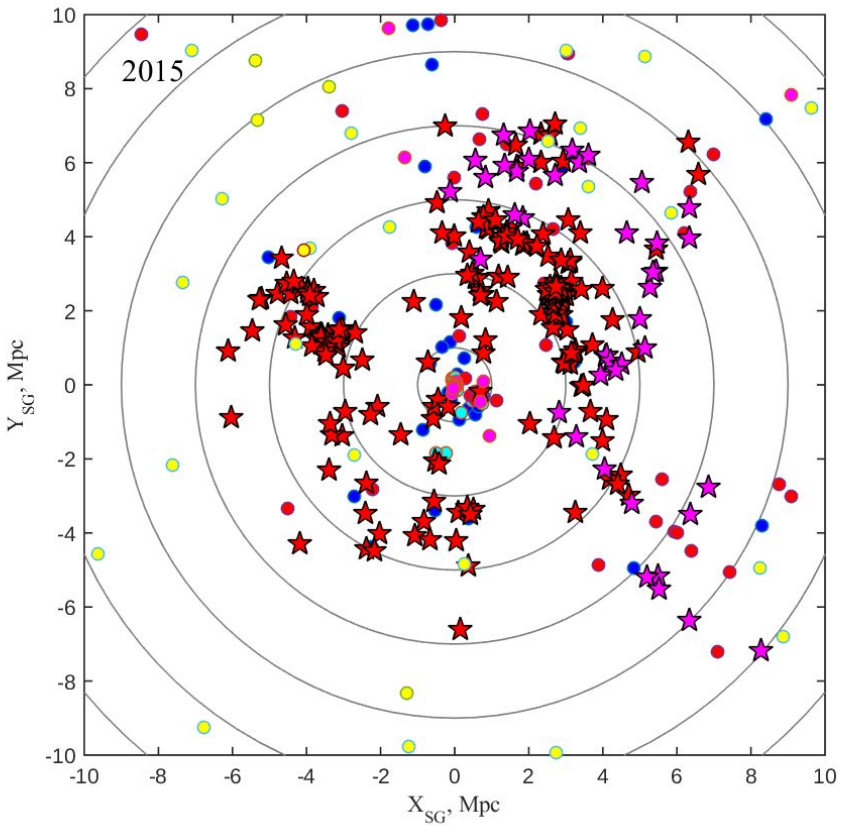
Karachentsev et al. (2015)



Jang & Lee (2017)



a) Hubble low



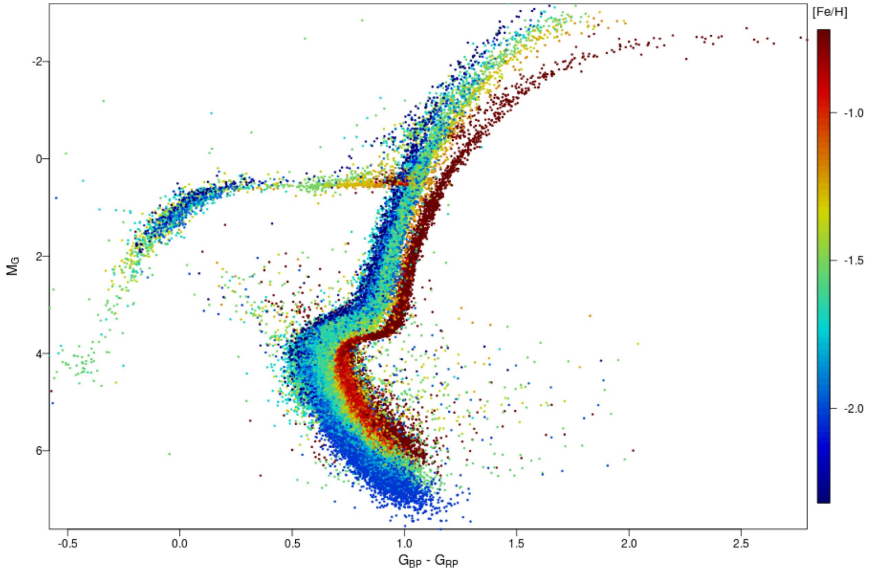
b) Spatial distribution

Comparison of different methods for determining distance, SAO group is asterisk (2015)

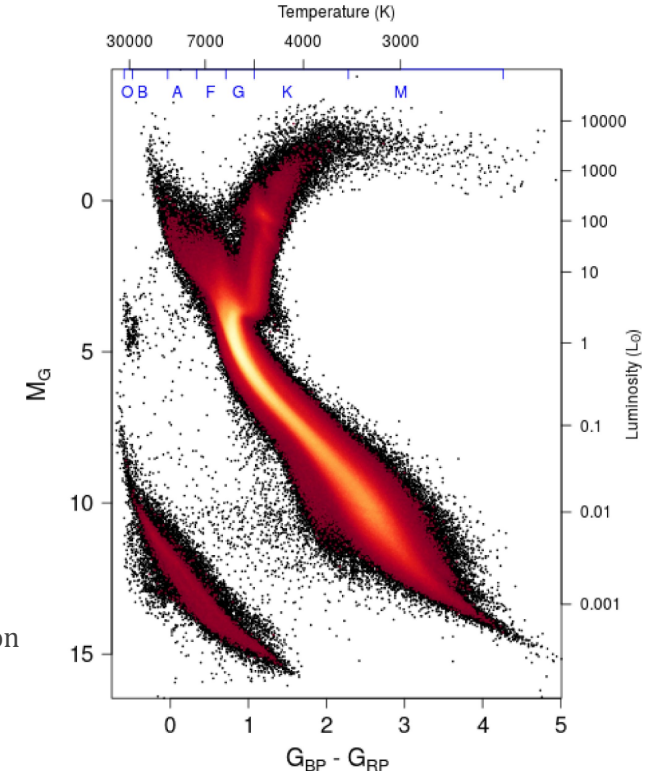
Gaia data release 2

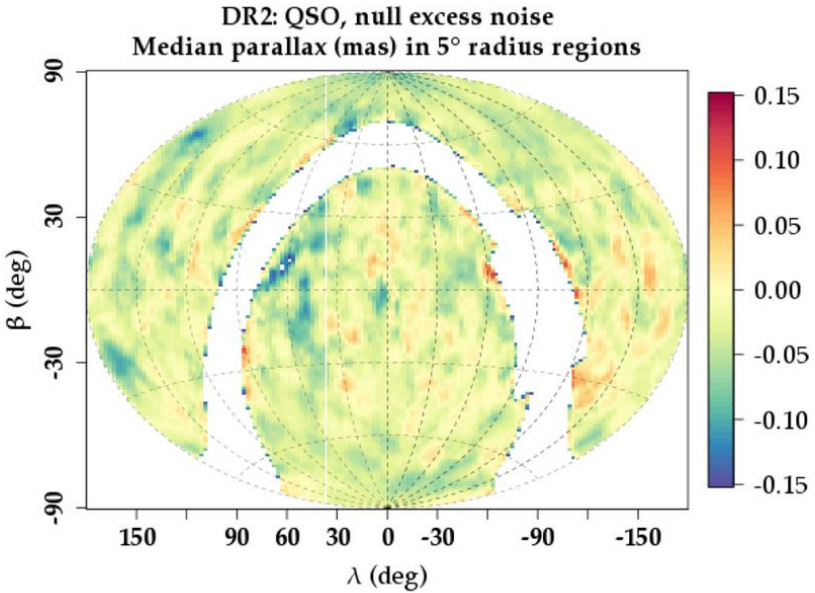
- Publication date: 25 April 2018
- Parallax accuracy: 0.03 mas for bright stars (1 mas for faint)
- 1693 million objects: 1332 million have parallaxes
- 3 passbands: white (general), red and blue

We got 3.8 million stars (of 53 million RGB stars in Gaia)



Gaia collaboration (2018a)



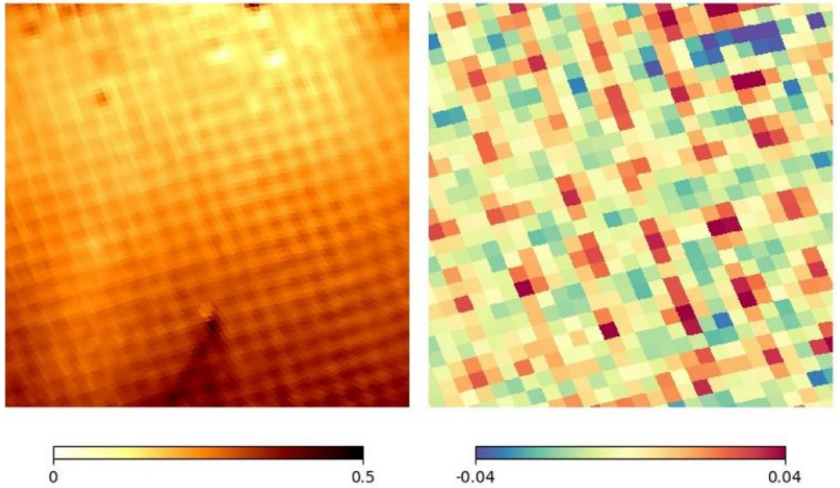


Variations in QSO parallaxes (mas) in 5° radius fields, ecliptic coordinates. In addition to a ≈–0.03 mas median zero-point, large-scale variations also appear in ecliptic longitude.

Gaia DR2: Catalogue validation, Arenou et al. (2018)

Systematics in parallaxes

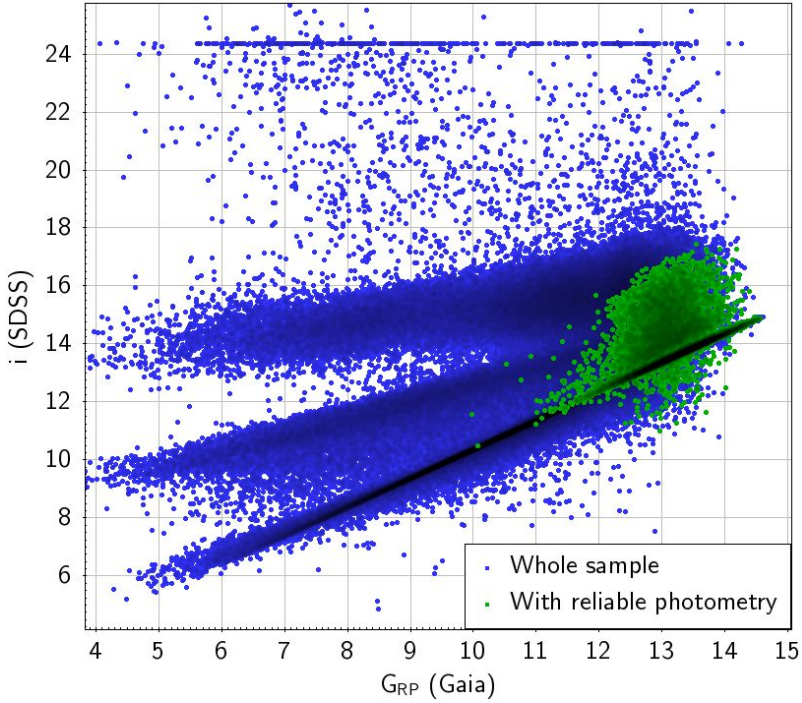
- significantly negative global zero point –0.030 mas
- small-scale correlations

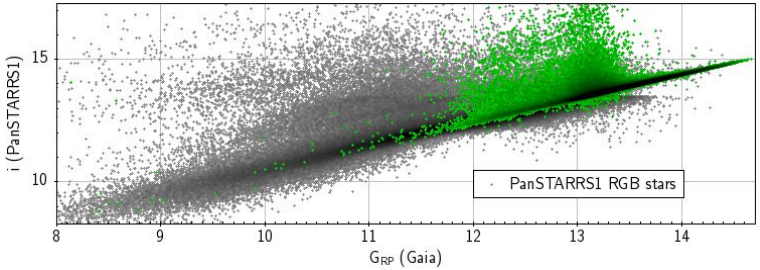


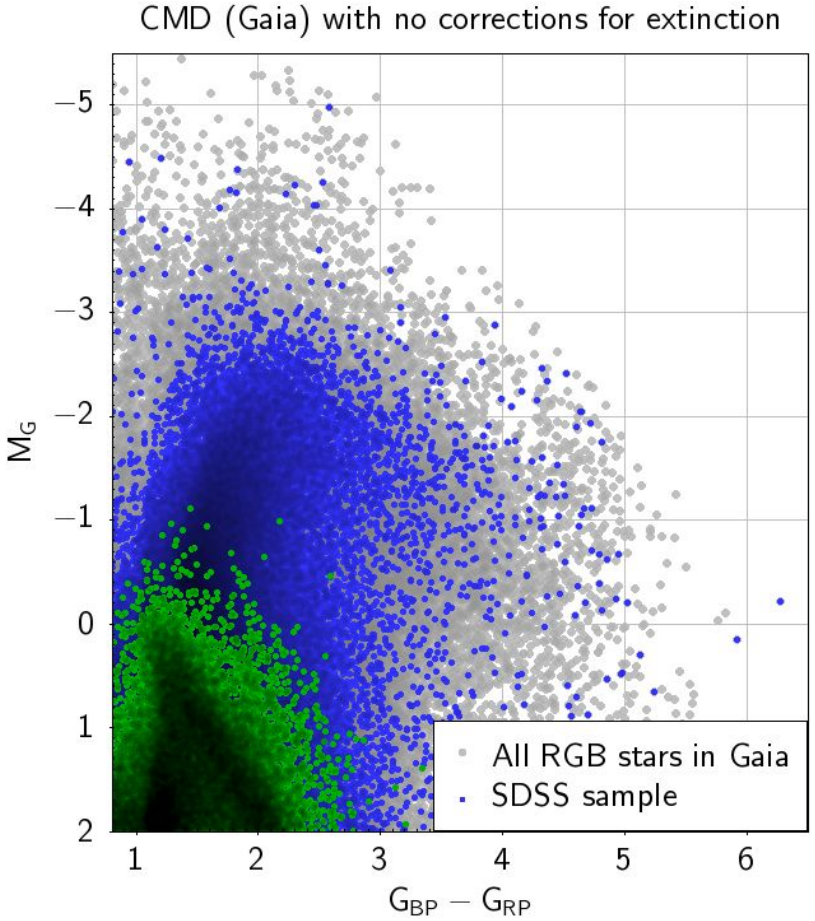
Small-scale systematics: map of median parallaxes (mas) in a 10° field centred on (*l*, *b*) =(0°,–12°) (*left panel*). Residuals (mas) of median parallaxes in field (1°,–7°), size 3° for stars brighter than $G = 17$ only, after subtracting a 0.7° running median (*right panel*).

Key steps:

- obtaining Gaia parallax data and photometry data
- correction stellar magnitudes for extinction
- the definition and application parameter restrictions
- building a color-magnitude diagram
- search for the exact position of the Tip of the RGB
- accounting for systematic errors


i (SDSS)
G_{RP} (Gaia)
Whole sample
With reliable photometry


i (PanSTARRS1)
G_{RP} (Gaia)
PanSTARRS1 RGB stars


CMD (Gaia) with no corrections for extinction
M_G
$G_{BP} - G_{RP}$
All RGB stars in Gaia
SDSS sample

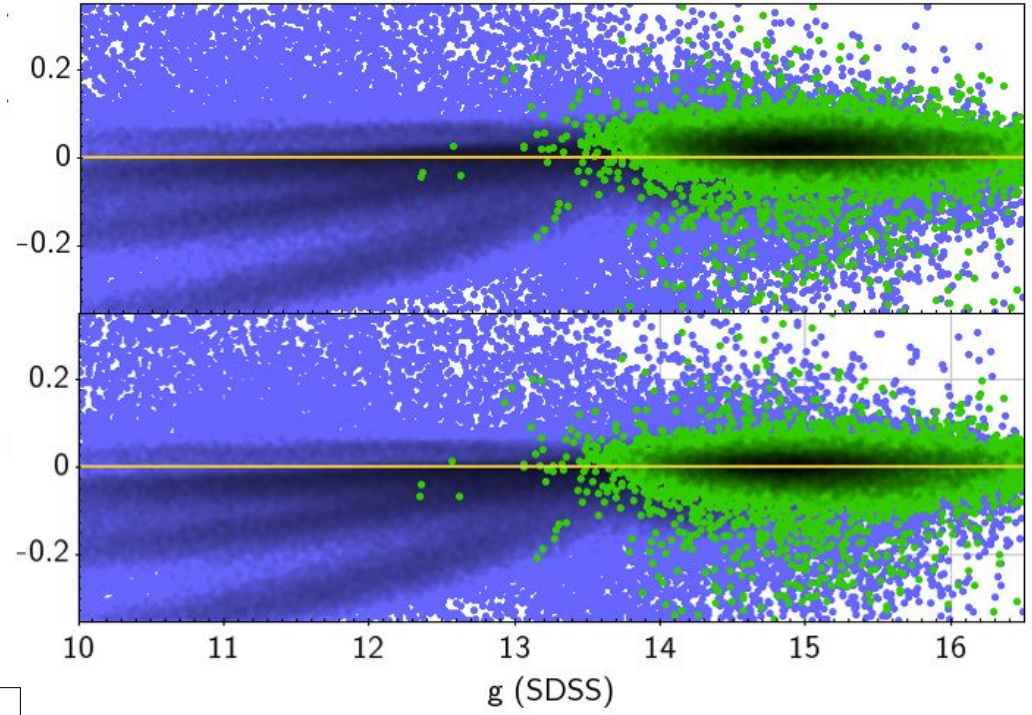
Evans et al. (2018)

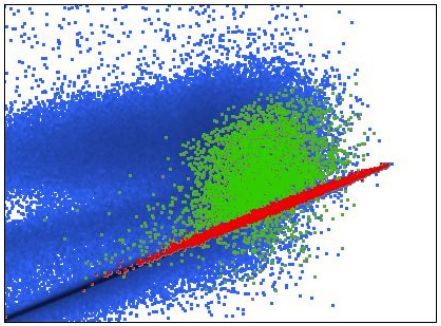
"Photometric content and validation"

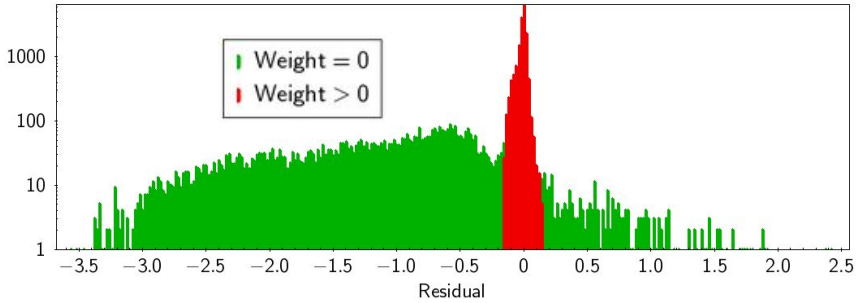
Robust regression:

3-degree polynomial

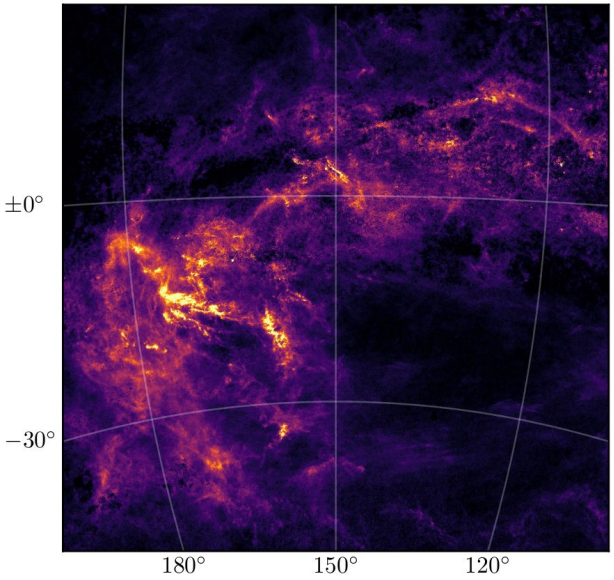
(this work)



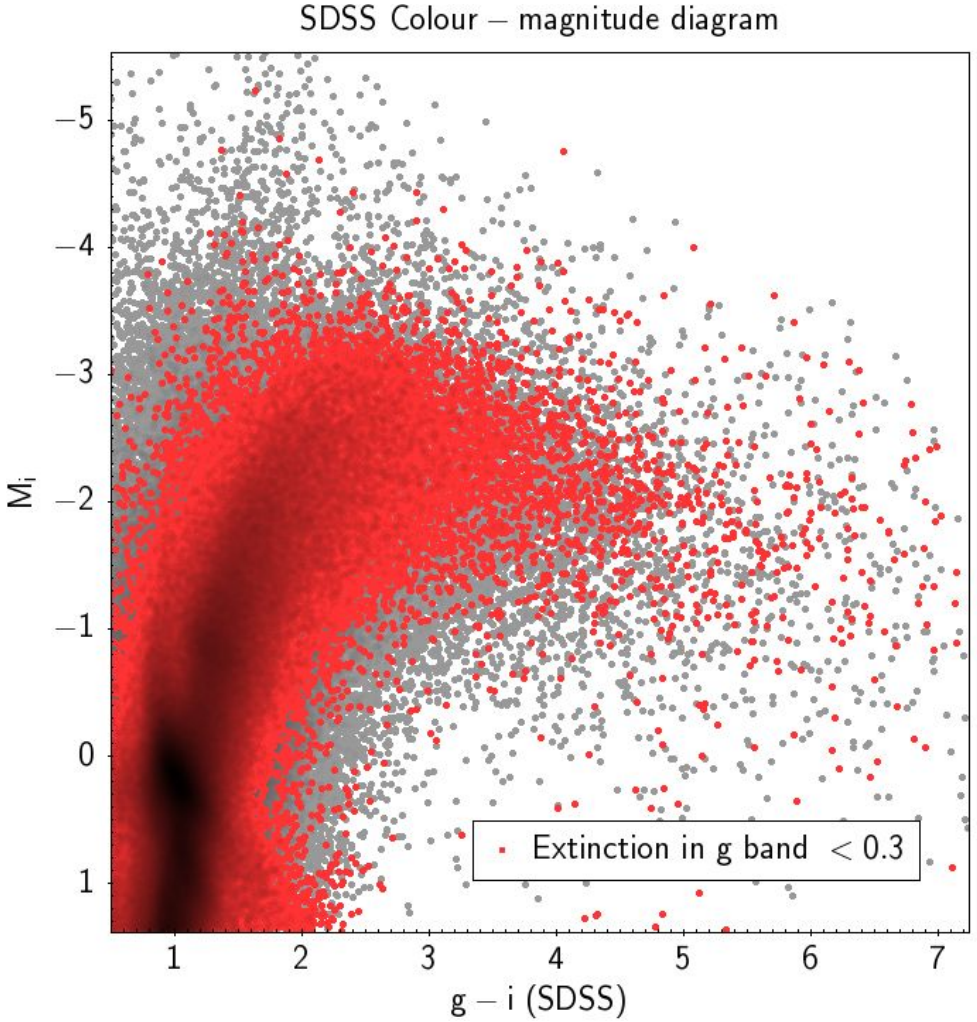


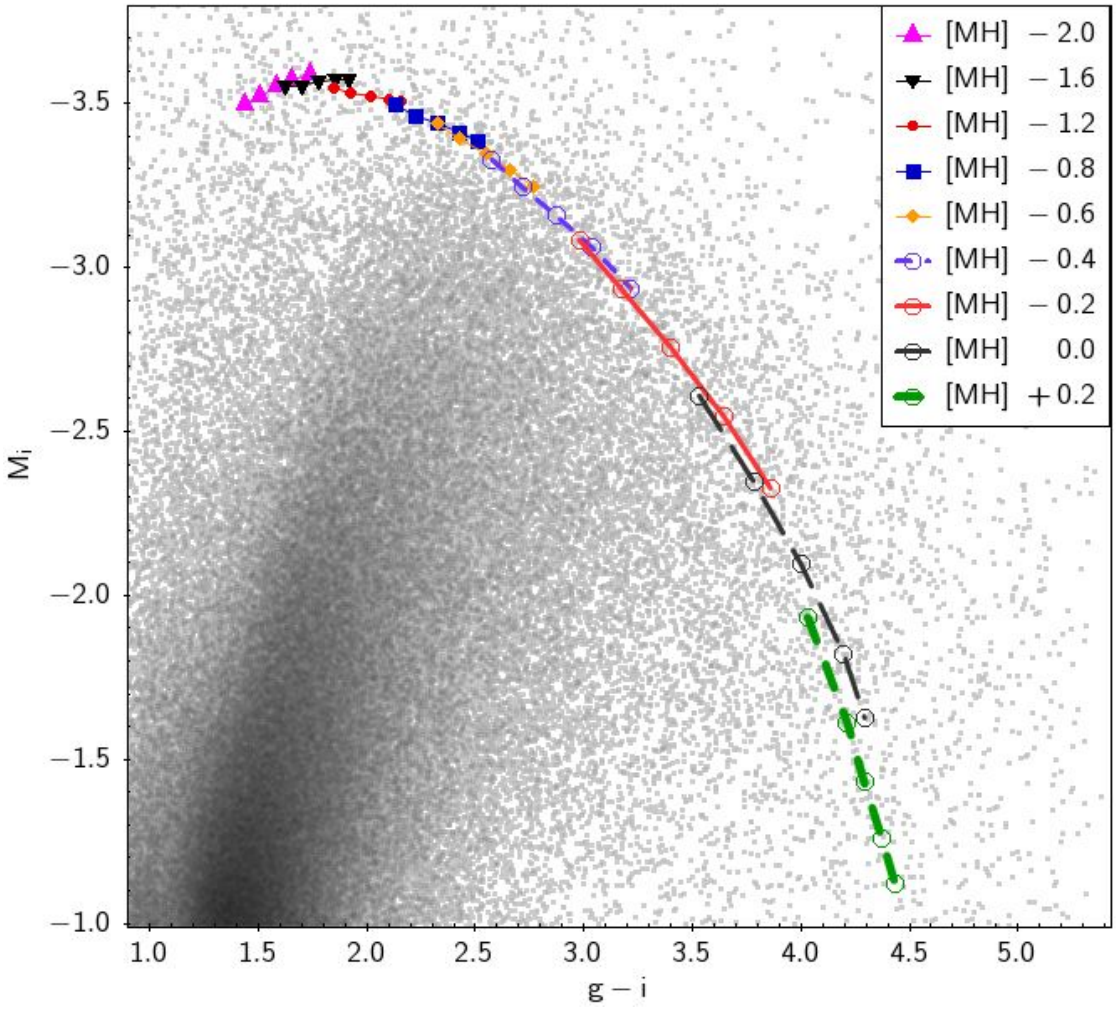


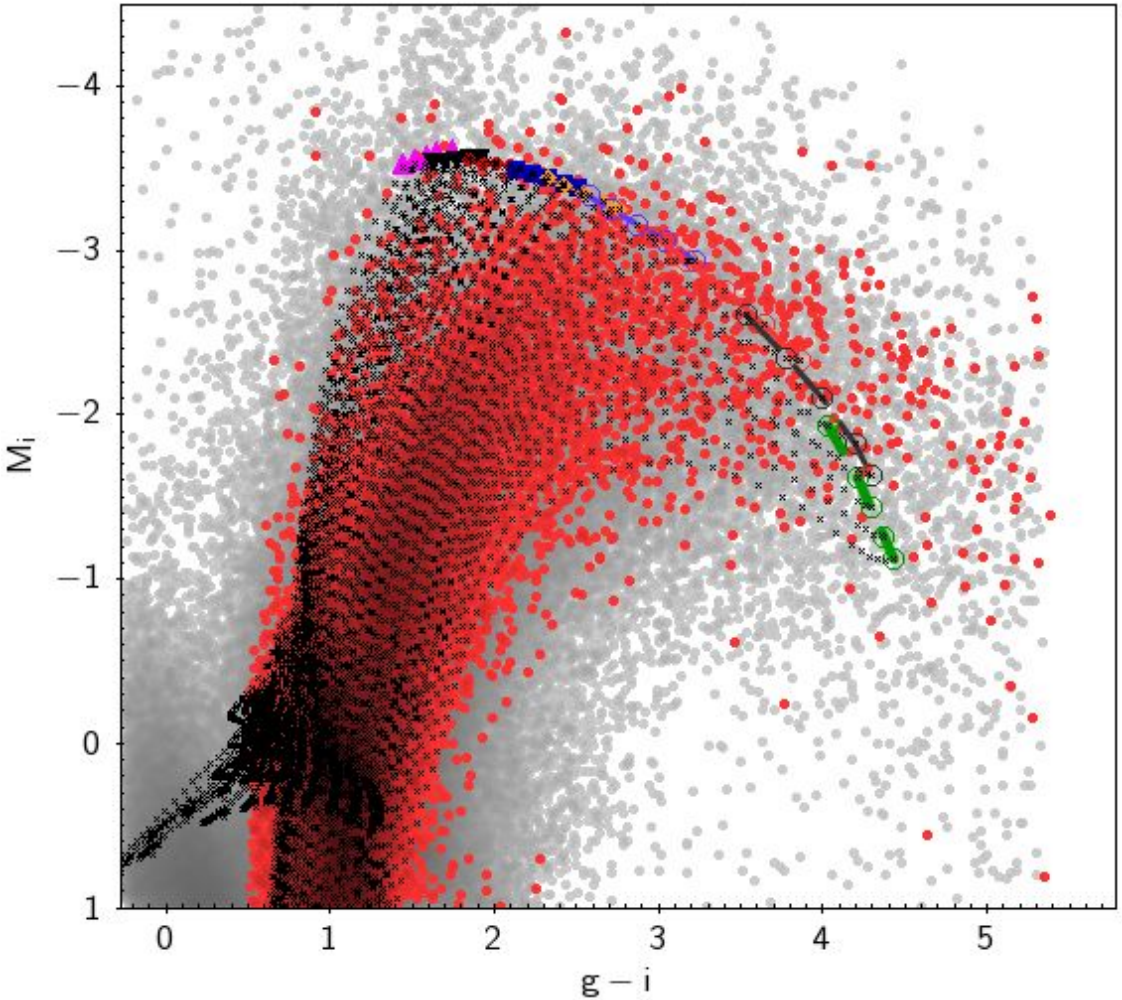
3D Dust Mapping
"Bayestar2019"

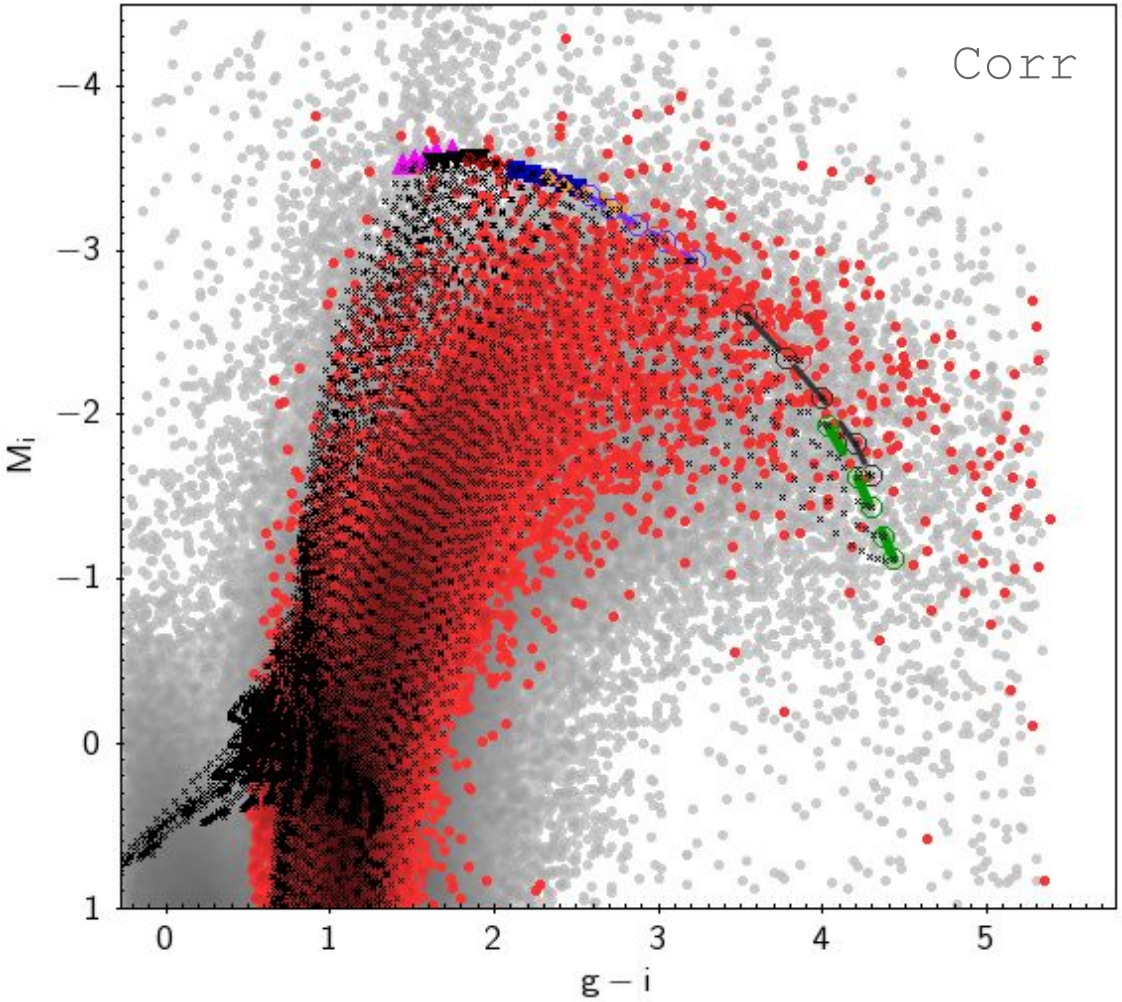


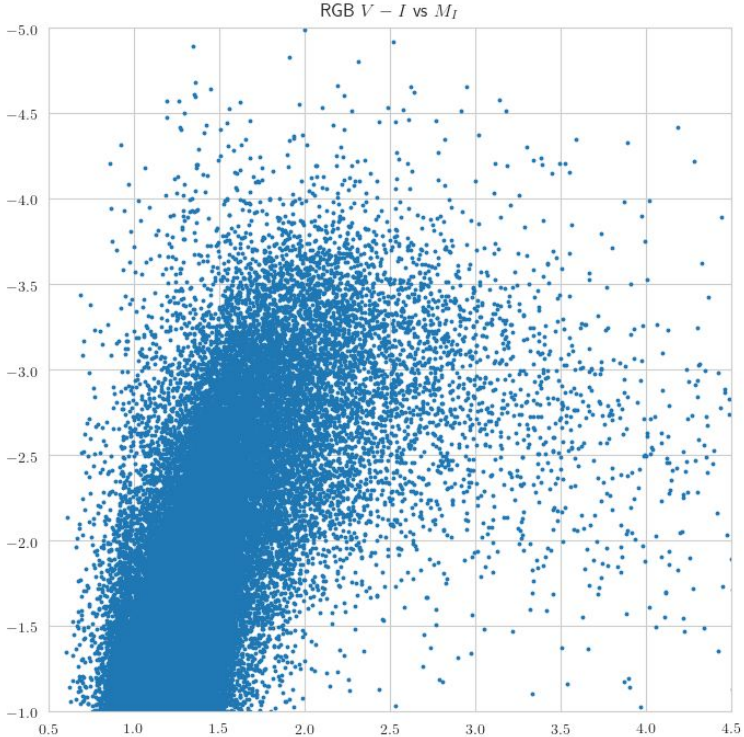
G. Green, E. Schlafly, D. Finkbeiner,
C. Zucker, J. Speagle (2019)

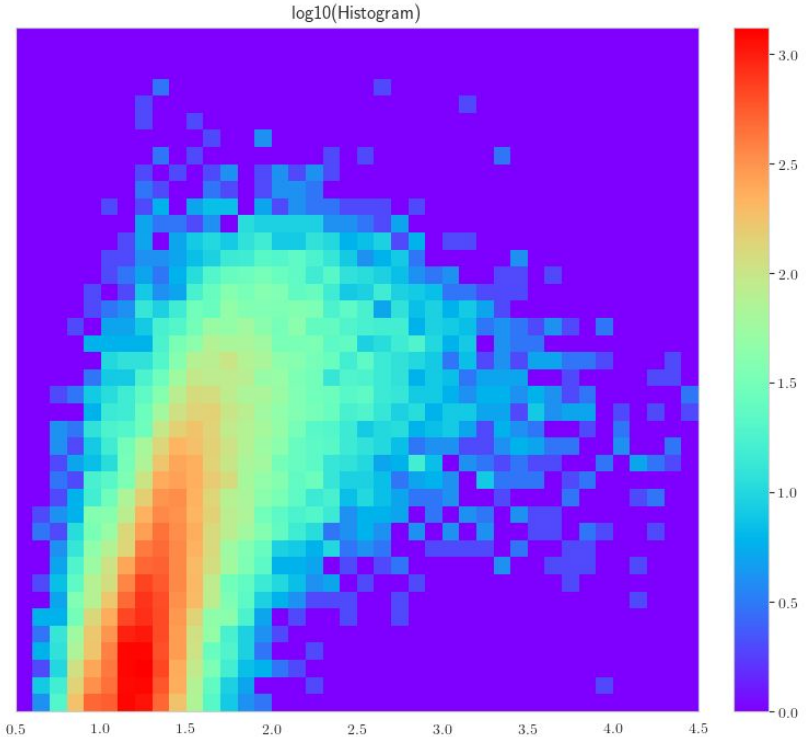



[MH] − 2.0
[MH] − 1.6
[MH] − 1.2
[MH] − 0.8
[MH] − 0.6
[MH] − 0.4
[MH] − 0.2
[MH] 0.0
[MH] + 0.2
−3.5
−3.0
−2.5
−2.0
−1.5
−1.0
M_i
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
g − i


−4
−3
−2
−1
0
1
M_i
0
1
2
3
4
5
g − i


Corr
−4
−3
−2
−1
0
1
M_i
0
1
2
3
4
5
g − i


RGB $V - I$ vs M_I
−5.0
−4.5
−4.0
−3.5
−3.0
−2.5
−2.0
−1.5
−1.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5


log10(Histogram)
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

$$f'(x) = (f(x + 2h) - f(x - 2h))/4h$$

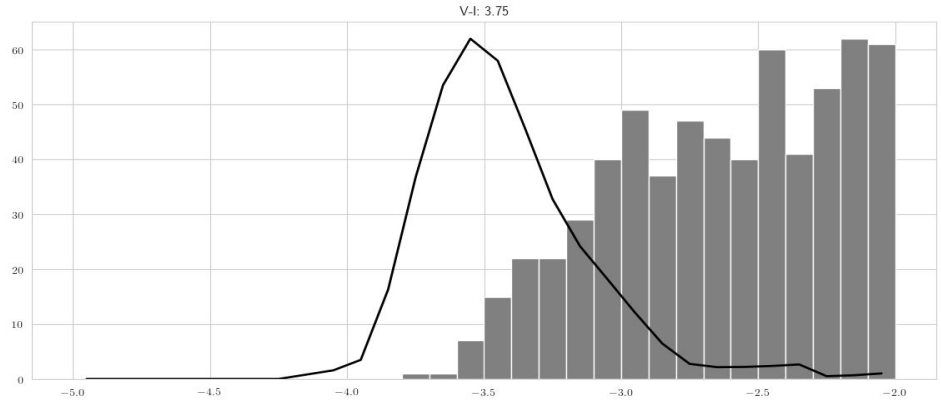
Edge Detection 2D convolution kernel

$$G_x =$$

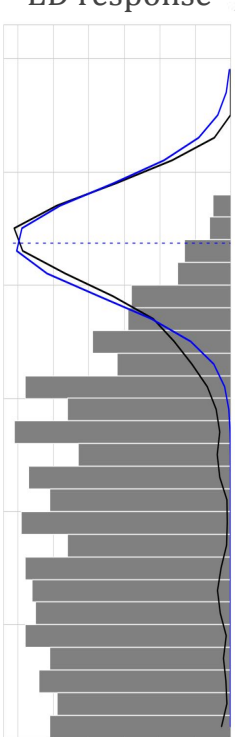
-0.25	-0.5	-0.25	0	0.25	0.5	0.25
-0.5	**-1**	-0.5	0	0.5	**1**	0.5
-0.25	-0.5	-0.25	0	0.25	0.5	0.25

$$G_y = G_x^{\mathrm{T}}, \qquad G = \sqrt{(\mathtt{Hist} * G_x)^2 + (\mathtt{Hist} * G_y)^2}$$

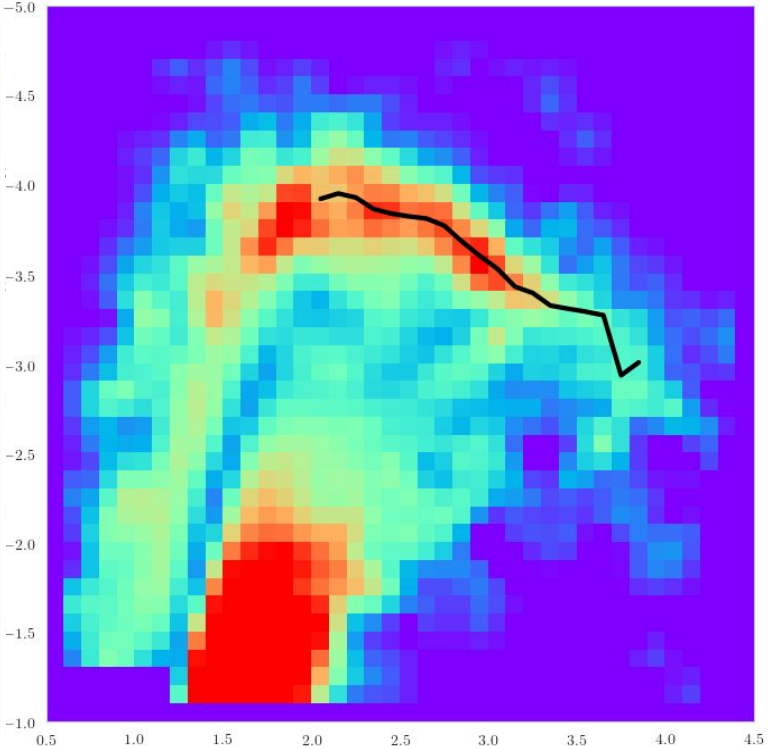
Edge Detection response



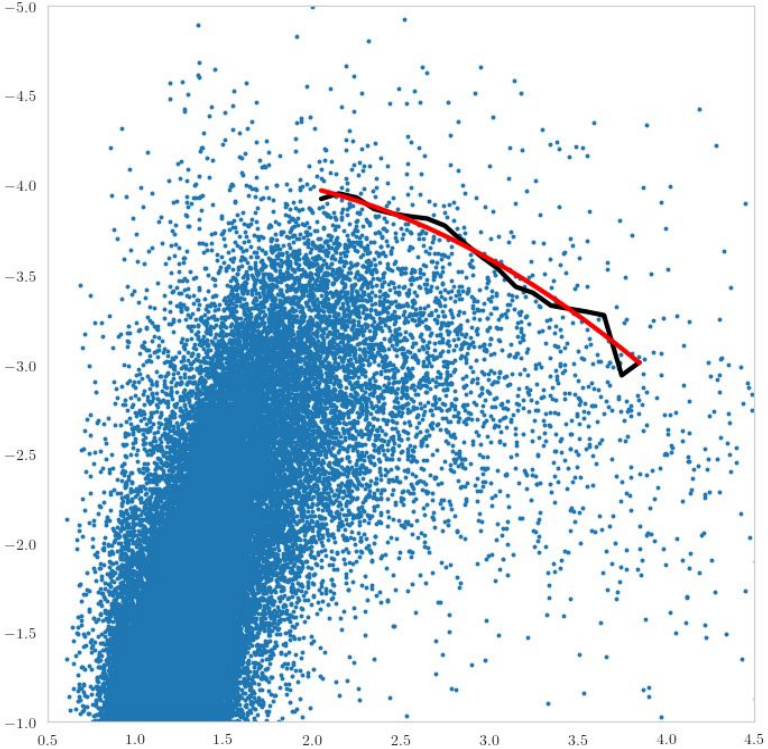
one column
ED response

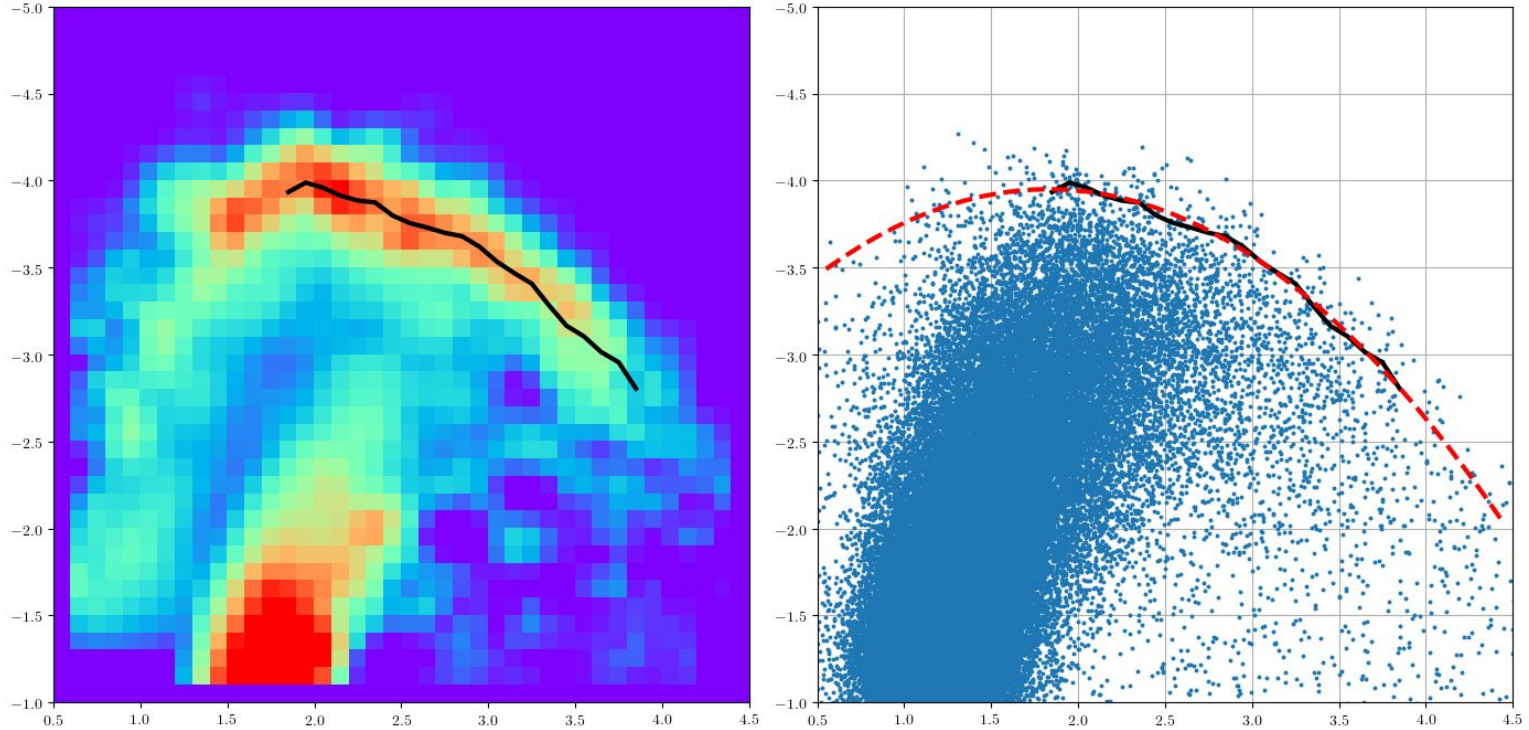


Edge Detection map with a
curve of the gaussian centers

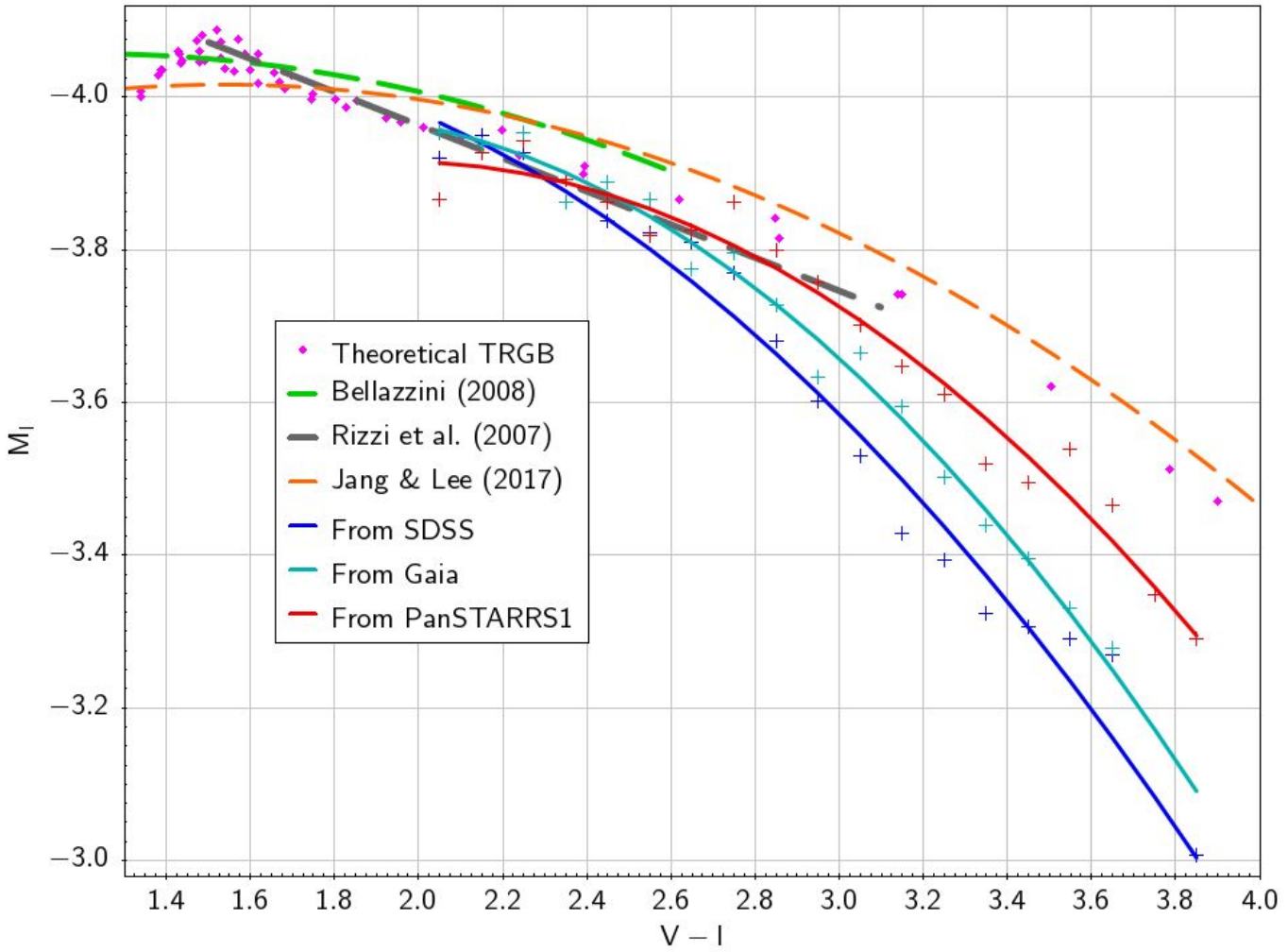


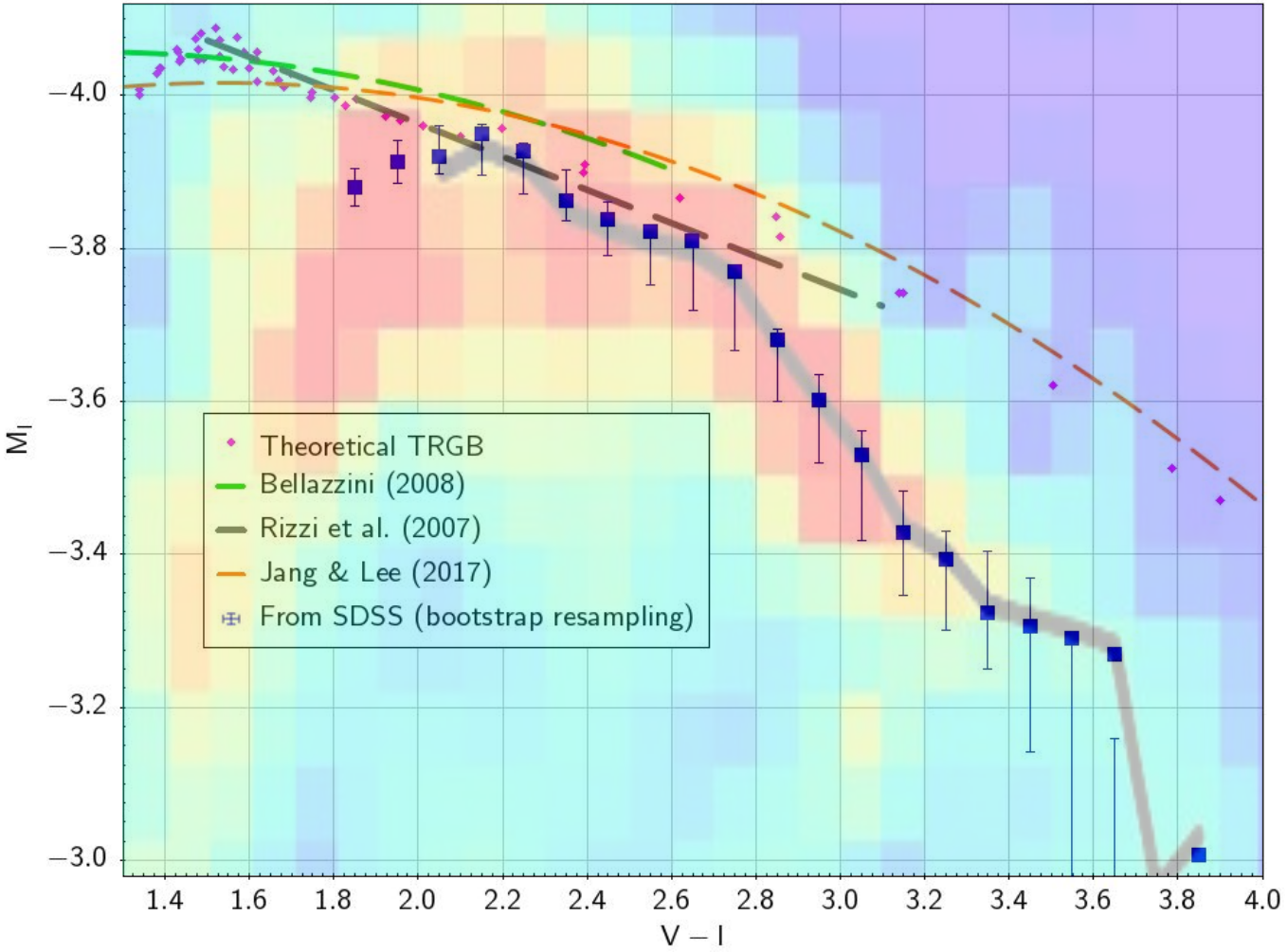
Fitting (parabola)

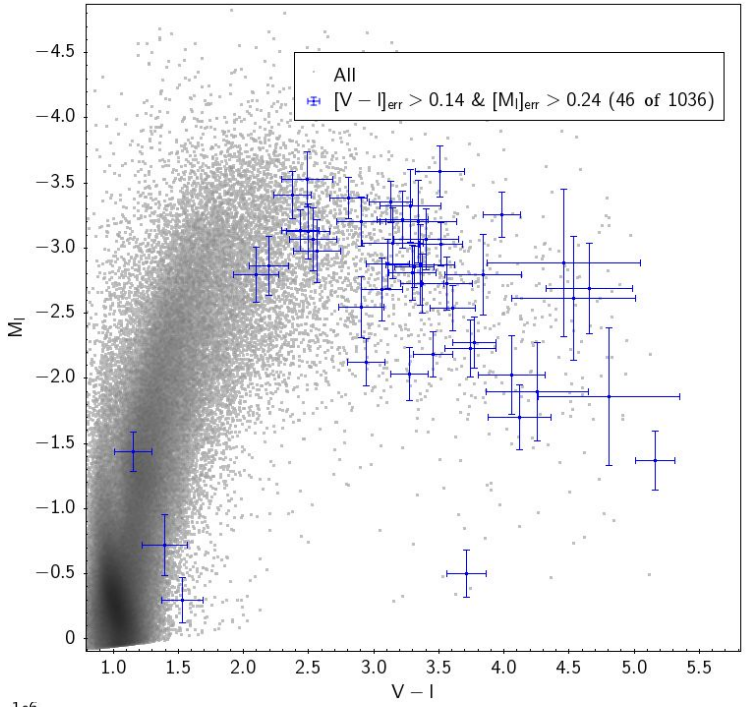




Model RGB stars (approximation of a real histogram by a polynomial surface). An artificial break (red parabola) added and random errors included.


Theoretical TRGB
Bellazzini (2008)
Rizzi et al. (2007)
Jang & Lee (2017)
From SDSS
From Gaia
From PanSTARRS1
M_I
$V - I$
−4.0
−3.8
−3.6
−3.4
−3.2
−3.0
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0

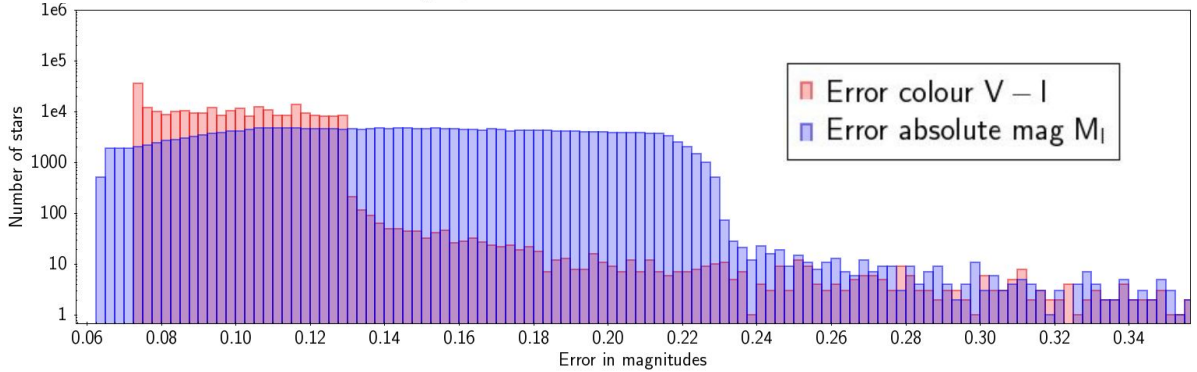

Theoretical TRGB
Bellazzini (2008)
Rizzi et al. (2007)
Jang & Lee (2017)
From SDSS (bootstrap resampling)
M_I
$V-I$
−4.0
−3.8
−3.6
−3.4
−3.2
−3.0
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0



Average errors in magnitudes

(TRGB region in the CMD):

- Gaia photometry ~ 0.001
- Transformations between Gaia and other photometric systems ~ **0.025**
- Correction for extinction ~ **0.02**
- Transformations to standard BVRI magnitudes ~ 0.015
- Parallax: 0.06 mas ~ **0.13 mag**

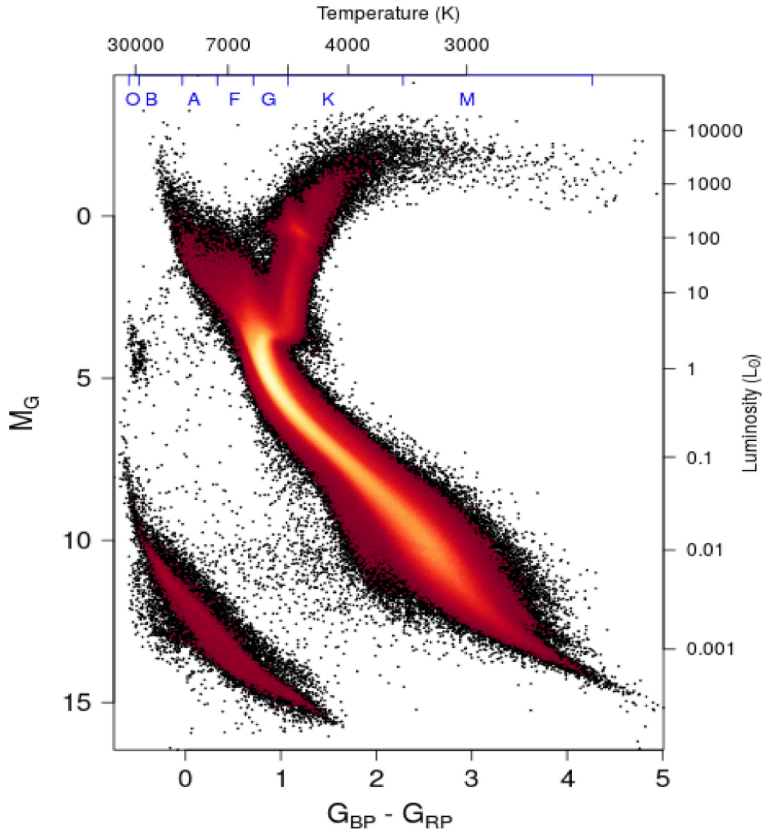


Our sample of RGB stars is **250 thousands** (0.4% of all Gaia objects in the RGB region)

Results:

- First TRGB calibration attempt on Galaxy stars
- Detailed analysis of the methodology and observational data
- Consistency with previous results in intermediate colours
- An algorithm has been prepared for determining TRGB in future work

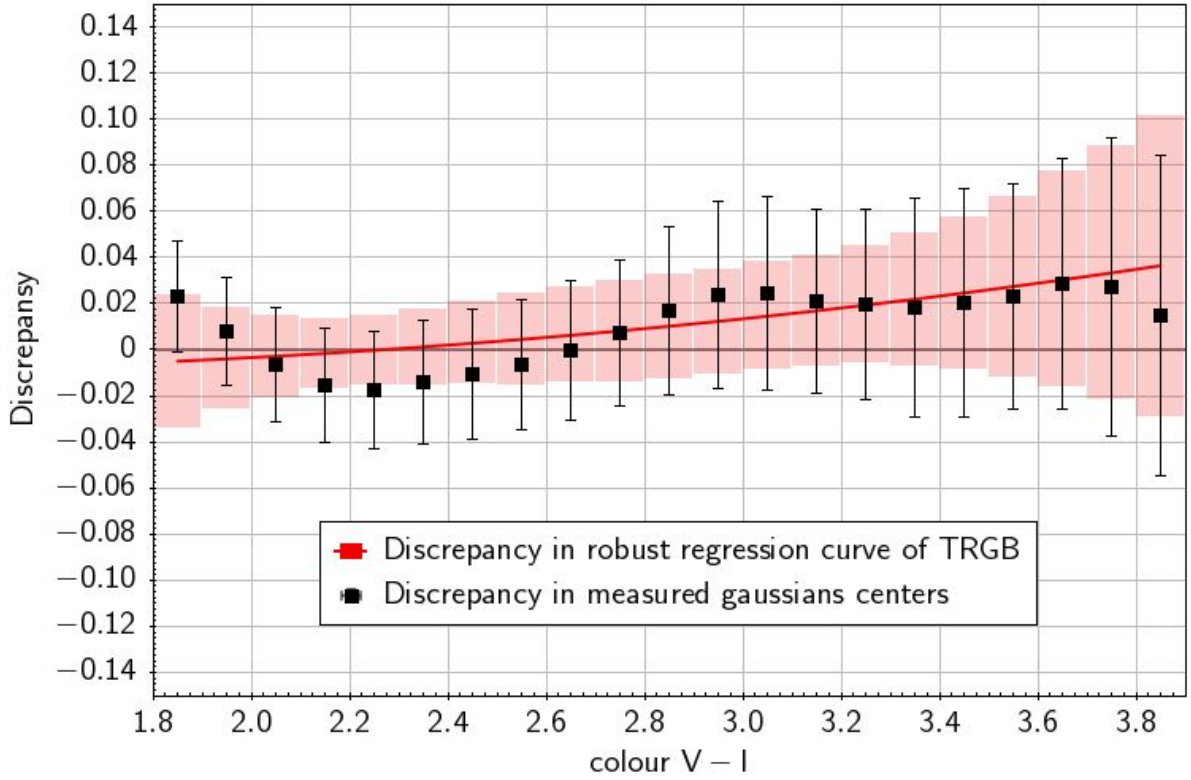
Thank you for your attention!



TRGB calibration using Gaia DR2

Usachev Pavel,

Makarov Dmitry


0.14
0.12
0.10
0.08
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
−0.08
−0.10
−0.12
−0.14
Discrepansy
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
colour V − I
Discrepancy in robust regression curve of TRGB
Discrepancy in measured gaussians centers