SIMULATION OF gaia CATALOGUE IN plato FIELDS

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IEEC
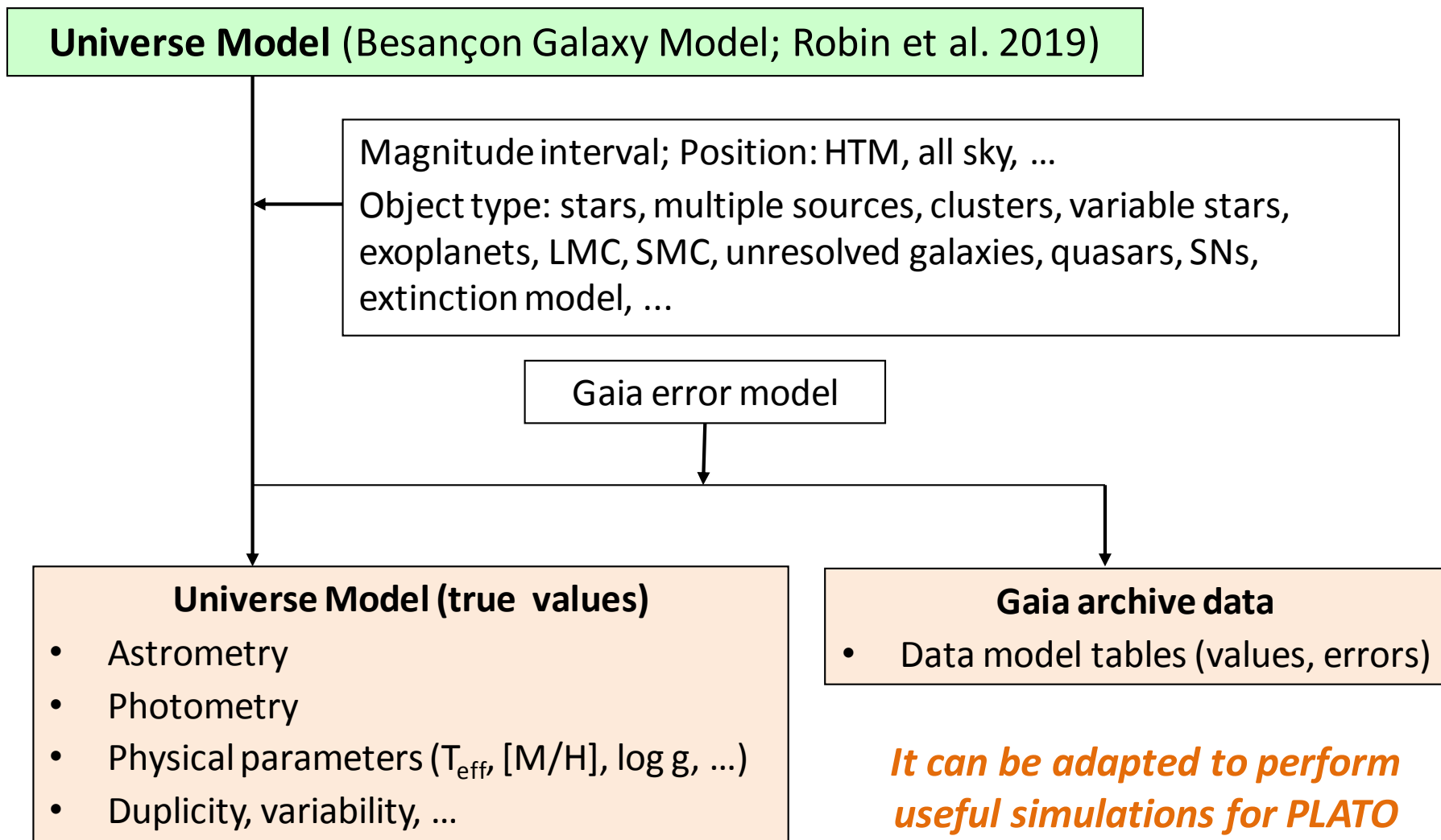Institut d'Estudis Espacials de Catalunya

PLATO-Gaia simulations (WP 131-150)

- Implement additional elements to Gaia simulator

- Provide a tool for the selection of PLATO fields

- Refine Gaia error models

- Simulate PLATO fields from Gaia input

- Photometric transformations

- Part of this work is available in the technical report PLATO-TN-UB-JMC-001.

- We offer the tool and/or the simulations to the PLATO community.

→ *Contact us. We are eager to help you*

Gaia Object Generator (GOG)

Avoid multiple simulators with different assumptions and models. Share expertise.

Universe Model (Besançon Galaxy Model; Robin et al. 2019)

Magnitude interval; Position: HTM, all sky, …

Object type: stars, multiple sources, clusters, variable stars, exoplanets, LMC, SMC, unresolved galaxies, quasars, SNs, extinction model, …

Gaia error model

Universe Model (true values)

- Astrometry
- Photometry
- Physical parameters (T_{eff}, [M/H], log g, …)
- Duplicity, variability, …

Gaia archive data

- Data model tables (values, errors)

It can be adapted to perform useful simulations for PLATO

PLATO PASSBAND

- PLATO passband from Marchiori et al (2019)
- Gaia-DR2 passbands (Maíz-Apellániz & Weiler, 2018), not pre-launch data from Jordi et al (2010).
- We extend Marchiori's Gaia-PLATO relationships to redder sources (A_{550}<11 mag) and other phot. systems (Johnson-Cousins, Hipparcos, Tycho, SDSS, 2MASS) .

Marchiori et al (2019)

PLATO will detect P, not V

Blue and red PLATO passband?
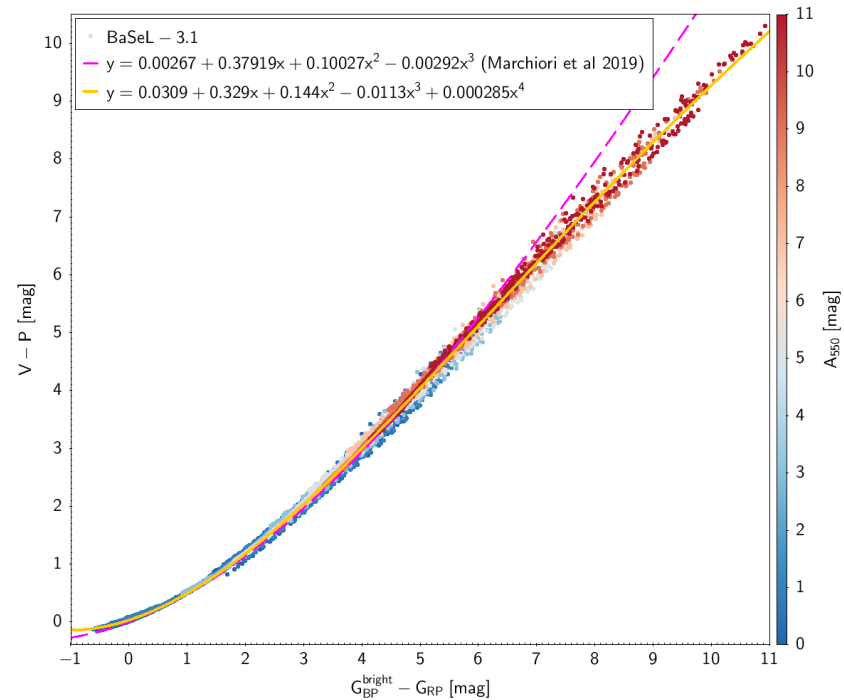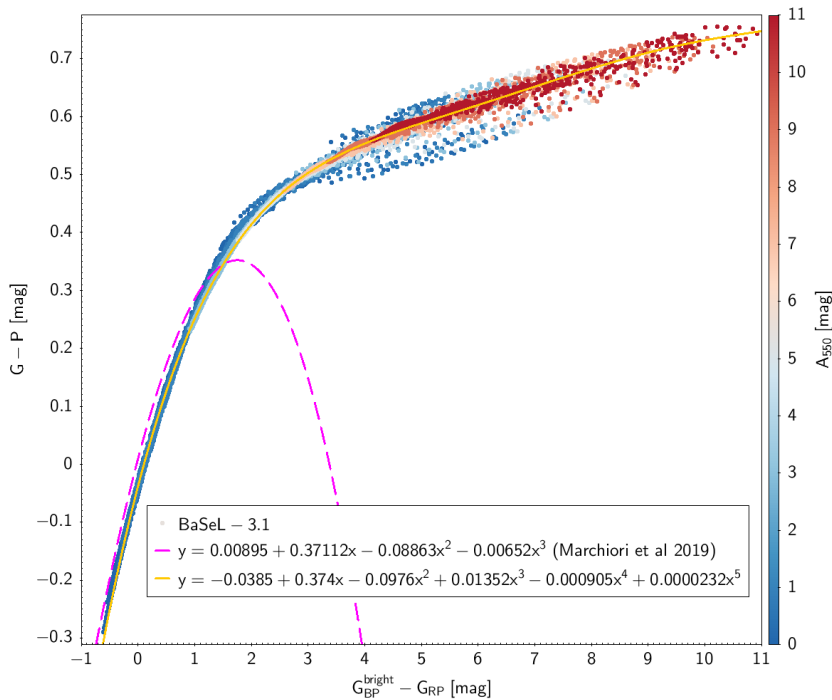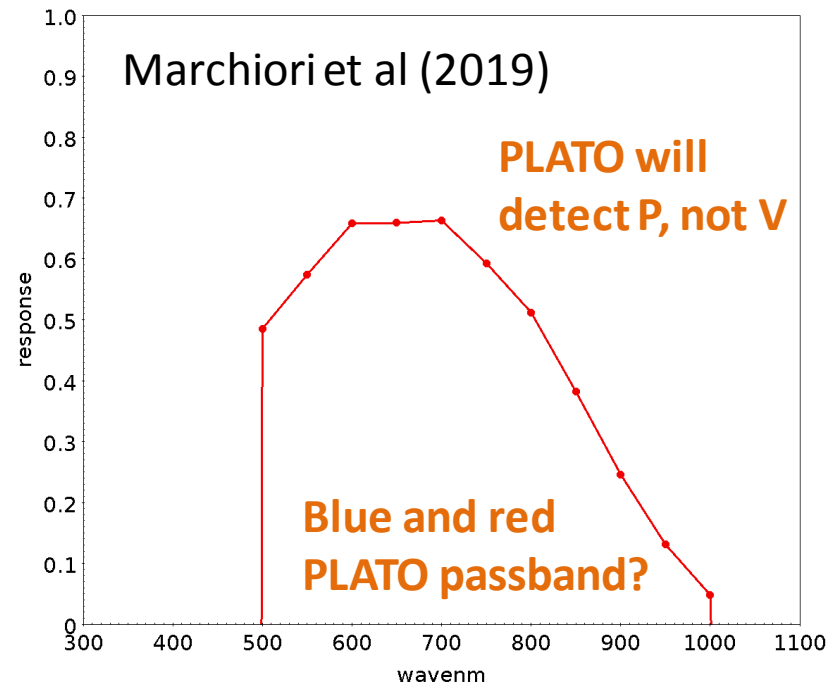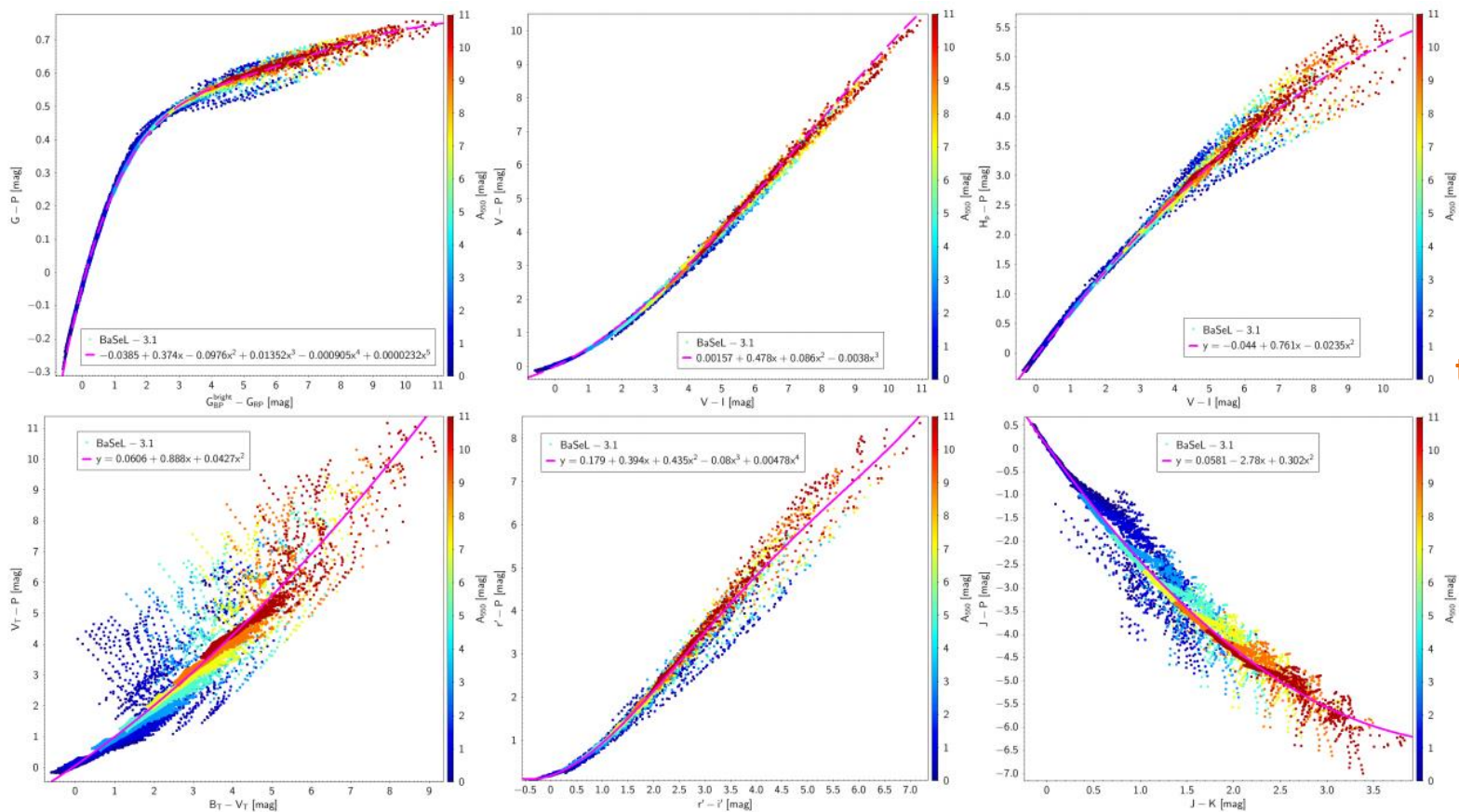
We did the photometric transformations for Gaia-DR2 (Evans+2018). Any request for Gaia-DR3? M stars? Other catalogues?

$$y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4 + a_5 x^5$$

	$y = f(x)$	a_0	a_1	a_2	a_3	a_4	a_5	σ
Gaia	$G - P = f\left(G_{BP}^{bright} - G_{RP}\right)$	-0.0385	0.374	-0.0976	0.01352	-0.000905	0.0000232	0.00869
	$V - P = f\left(G_{BP}^{bright} - G_{RP}\right)$	0.0309	0.329	0.144	-0.0113	0.000285	-	0.0502
Johnson	$V - P = f(V - I_c)$	0.00157	0.478	0.086	-0.0038	-	-	0.0556
Hipparcos	$H_p - P = f(V - I)$	-0.044028	0.761	-0.0235	-	-	-	0.0757
Tycho	$V_T - P = f(B_T - V_T)$	0.060569	0.88823	0.04268	-	-	-	0.530
SDSS	$r' - P = f(r' - i')$	0.179	0.394	0.435	-0.08	0.00478	-	0.107
2MASS	$J - P = f(J - K)$	0.058	-2,78	0.302	-	-	-	0.221

GOG-PLATO SIMULATIONS

Phot. transformations can be used to know P magnitudes:

Content in Northern and Southern PLATO Fields:

- NPF (l: 65º, b: 30º; r=27º), P < 11 mag
  GOG simulations: 94000 sources ←→ Gaia-DR2: 92045 sources

- SPF (l= 253º, b= -30º; r=27º), P < 11 mag
  GOG simulations: 93600 sources ←→ Gaia-DR2: 84307 sources
  (LMC not yet complete in Gaia-DR2)


NPF

SPF
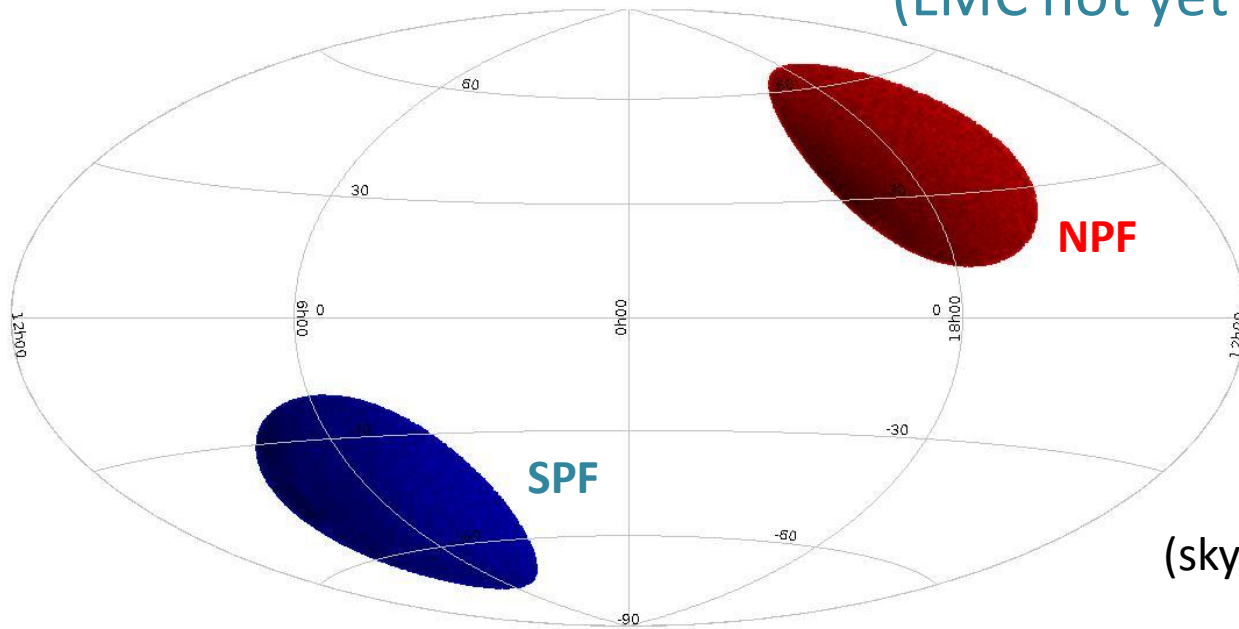
We can derive P for all stars in PIC catalogue

(skymap in equatorial coordinates)

Background estimation

- We sum fluxes of all Gaia-DR2 sources with G>11 mag in the area defined by 9 pixels wide (135x135 arcsec^2)

- No zodiacal light contribution considered

- Gaia ZP from Evans et al 2018

$$G = -2.5 \log \left(\frac{\sum F}{135 \times 135} \right) + 25.7934$$

Background G	Mean	SD	Minimum	Maximum
NPF	25.3656	2.06809	18.35791	32.19283
SPF	25.6546	2.02195	18.64412	32.25911
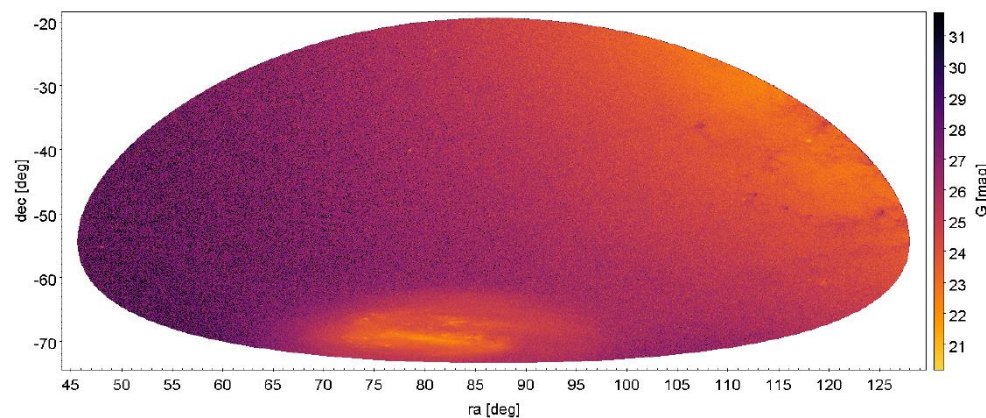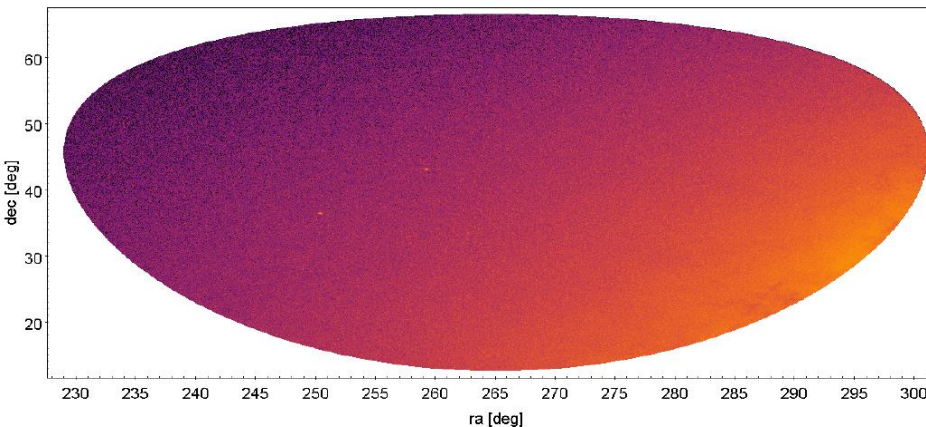
Sources in PLATO fields (Parallax)
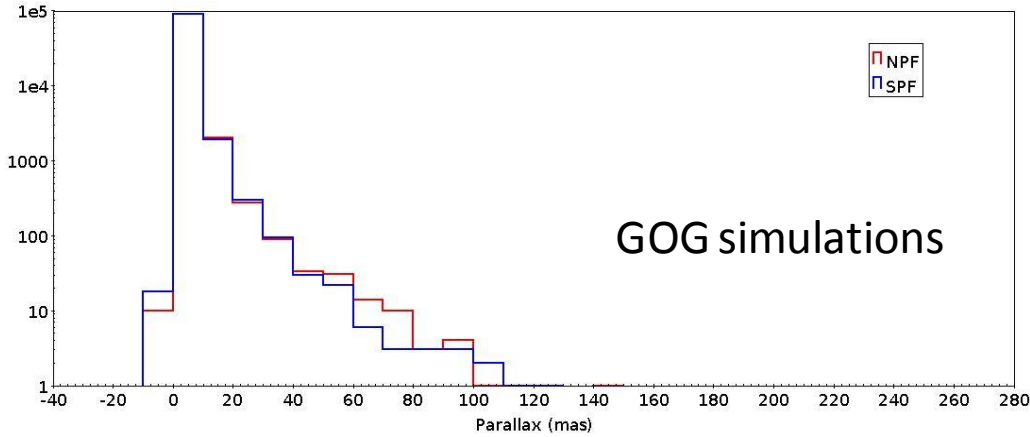
GOG simulations

Distance (pc)	NPF		SPF	
	Sources	%	Sources	%
0-100	2458	3	2370	3
100-200	7931	8	8144	9
200-500	26193	28	27670	30
500-1000	25758	27	25816	28
1000-2000	21702	23	20721	22
> 2000	9958	11	8863	9

Distances from GOG simulations

Gaia DR2
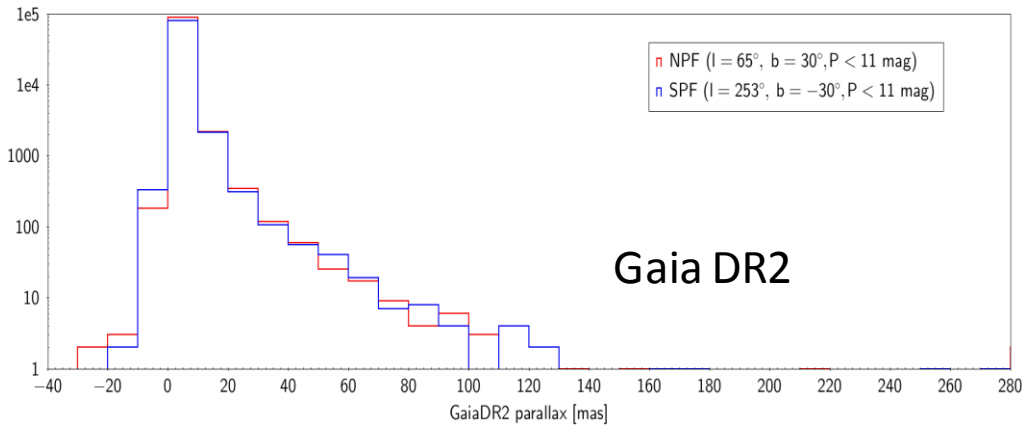
| Distance (pc)	NPF		SPF	
	Sources	%	Sources	%
0-100	2787	3	2712	3
100-200	8696	10	8674	10
200-500	27745	30	26254	31
500-1000	22658	25	21301	25
1000-2000	20673	23	17974	21
> 2000	8866	10	6766	8

Distances from Bailer-Jones et al, 2018

Colours & parallax

- We can predict with the photom. relationships the P magnitude from Gaia-DR2 magnitudes

- $G-P=f(G_{BP}-G_{RP})$ can only be applied in $-1<G_{BP}-G_{RP}<11$ mag.
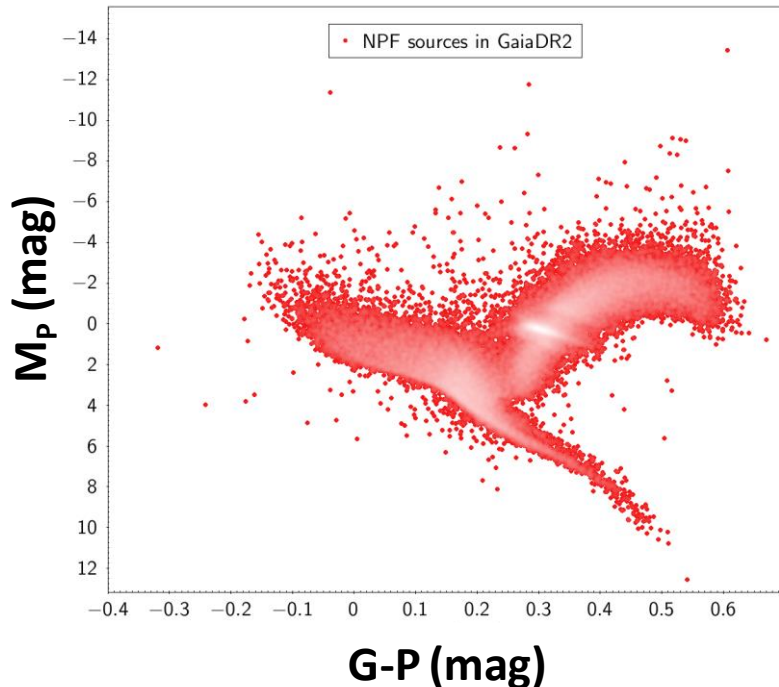
If blue and red passband were know, PLATO HR diagrams could be simulated
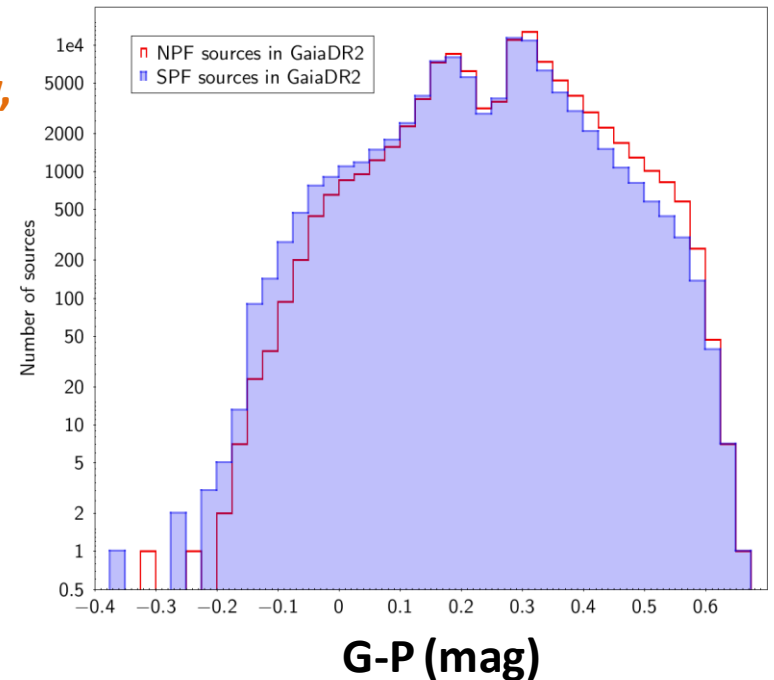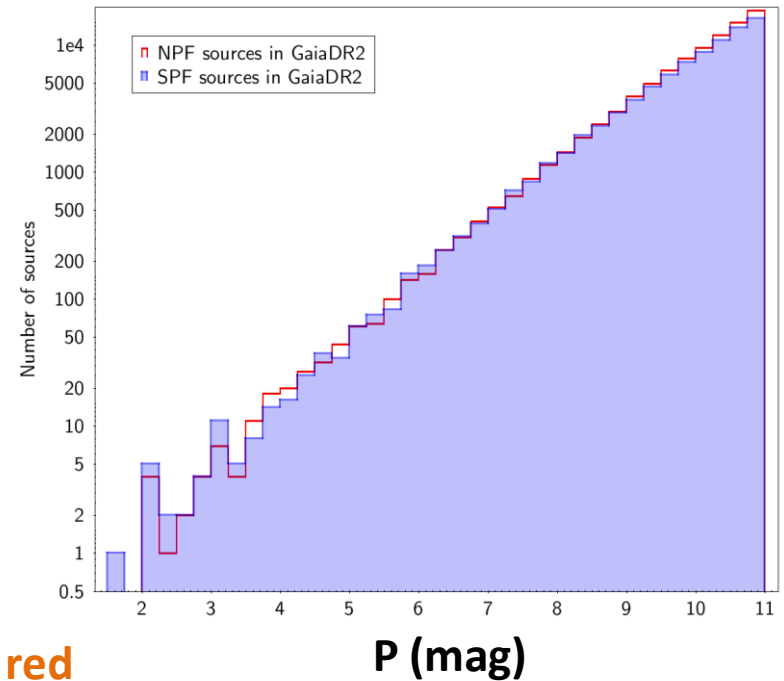
Sources in PLATO fields (Spectral types)

Gaia-DR2

Type	T_{eff}	NPF		SPF	
		Sources	Fraction	Sources	Fraction
O	$\geq 30000\ K$	1	0%	3	0%
B	10000-30000 K	1571	2%	2805	4%
A	7500-10000 K	4969	7%	5807	9%
F	6000-7500 K	17871	25%	17805	26%
G	5200-6000 K	8011	11%	7276	11%
K	3700-5200 K	33638	46%	30391	44%
M	2400-3700 K	6231	9%	4145	6%

GOG simulations provide precise temperatures, not from estimations.

Type	T_{eff}	NPF		SPF	
		Sources	Fraction	Sources	Fraction
O	$\geq 30000\ K$	10	0%	22	0%
B	10000-30000 K	1613	2%	1919	2%
A	7500-10000 K	6656	7 %	7864	8%
F	6000-7500 K	19638	21%	20742	22%
G	5200-6000 K	7822	8 %	8059	9%
K	3700-5200 K	52016	55%	48709	52%
M	2400-3700 K	6043	6%	5876	6%

GOG

Gaia-DR2

Gaia-DR2

GOG
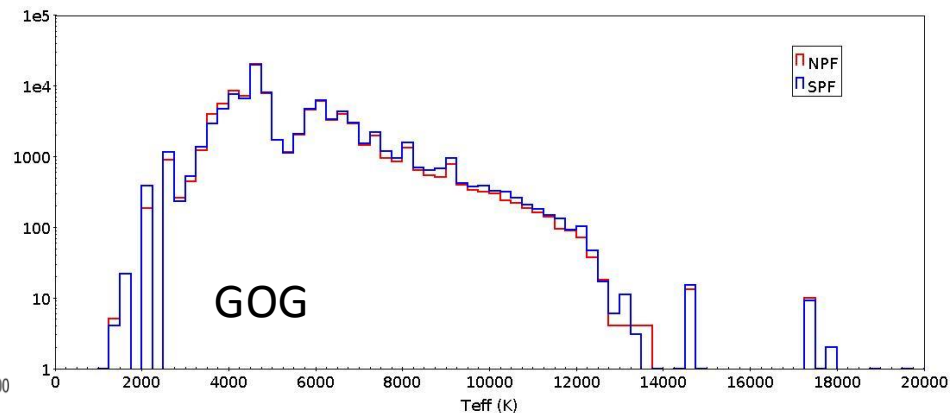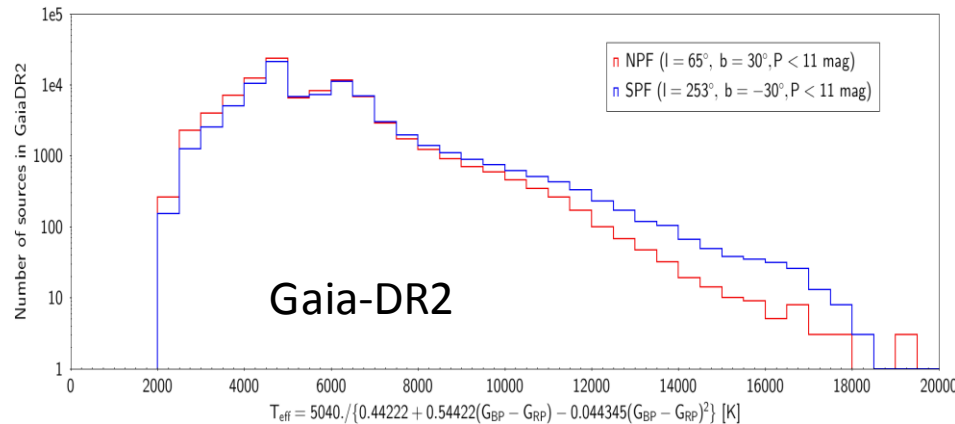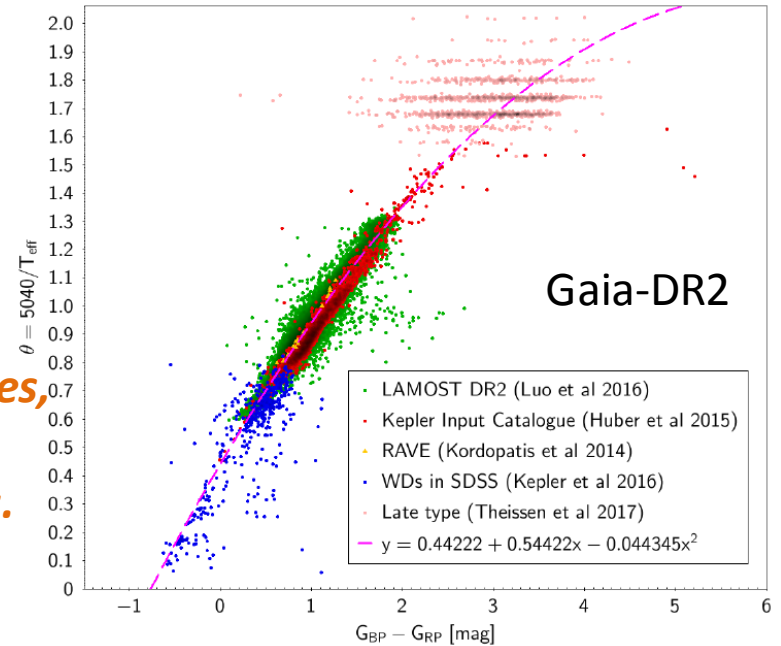
Gaia-DR2 performances
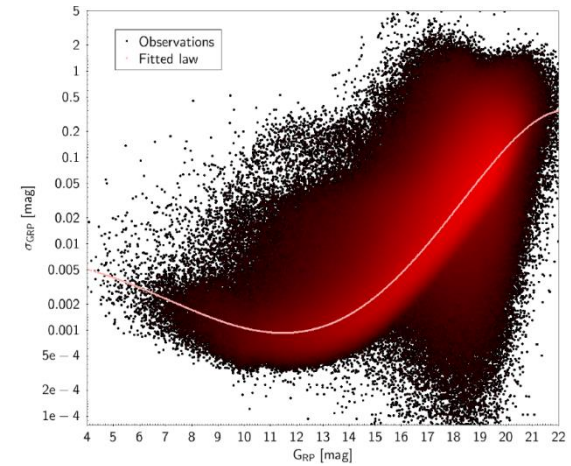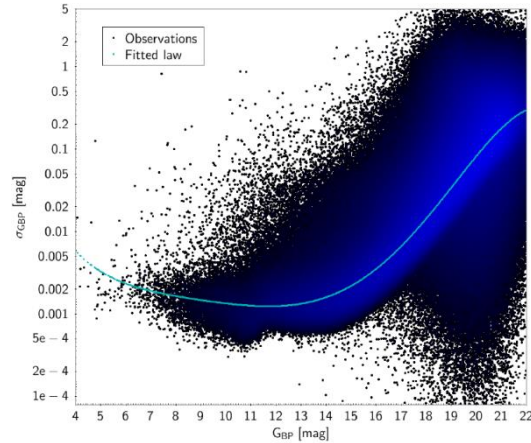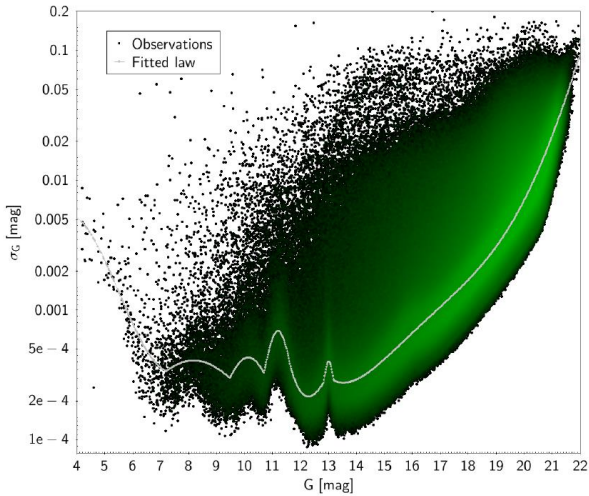
Fitted uncertainty	Magnitude range	A_0	A_1	A_2	A_3	A_4	A_5
$\log(\sigma_{BP})$	$6 < G_{BP} < 21$	1.3279	-1.7832	0.32006	-0.029038	0.00127305	-0.000020676
$\log(\sigma_{RP})$	$6 < G_{RP} < 21$	-2.1082	-0.045002	0.012918	-0.004909	0.00041313	-0.000009338
Fitted uncertainty	Magnitude range	A_0	A_1	A_2	A_3	A_4	A_5
$\log(\sigma_G)$	$4 \leq G < 7.205$	-8.4057	4.006	-0.8162	0.04931	-	-
$\log(\sigma_G)$	$11.665 \leq G < 12.84$	366.221	-84.6518	6.42937	-0.161951	-	-
$\log(\sigma_G)$	$13.187 \leq G$	361.745	-104.1089	11.72489	-0.65267	0.0179603	-0.00019499
Fitted uncertainty	Magnitude range	γ	β	α			
$\ln[\log(\sigma_G) + 4]$	$7.205 \leq G < 9.481$	-10.4559	2.4342	-0.14866	-	-	-
$\ln[\log(\sigma_G) + 4]$	$9.481 \leq G < 10.698$	-68.4827	13.4197	-0.66181	-	-	-
$\ln[\log(\sigma_G) + 4]$	$10.698 \leq G < 11.665$	-242.2847	43.2316	-1.92987	-	-	-
$\ln[\log(\sigma_G) + 4]$	$12.84 \leq G < 13.187$	-1631.225	250.517	-9.62133	-	-	-

Gaia Performances (GOG)

Gaia-DR2

End of nominal Gaia mission
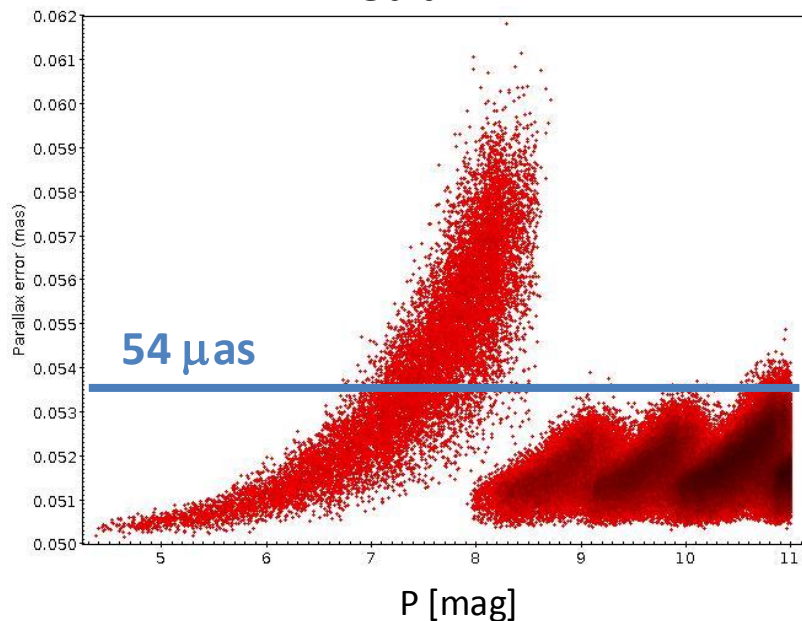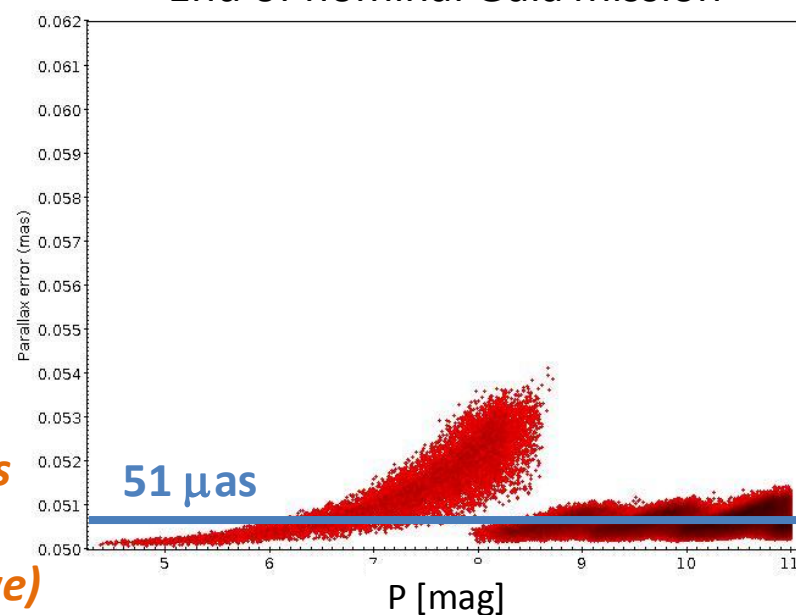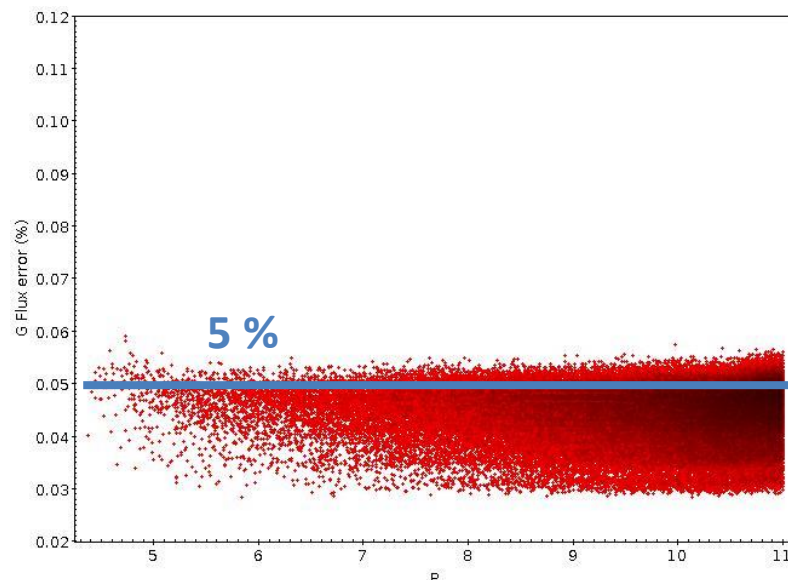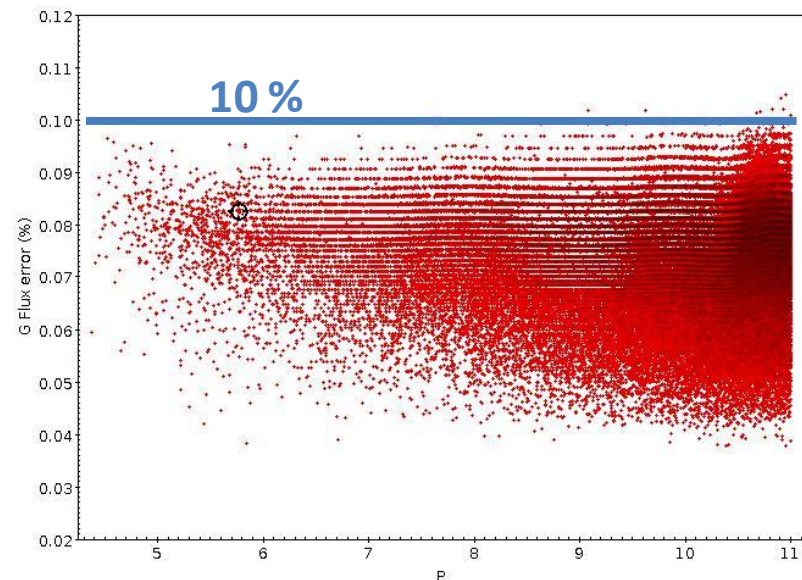
Parallax error

σ_{cal}=50 μas was used (conservative)

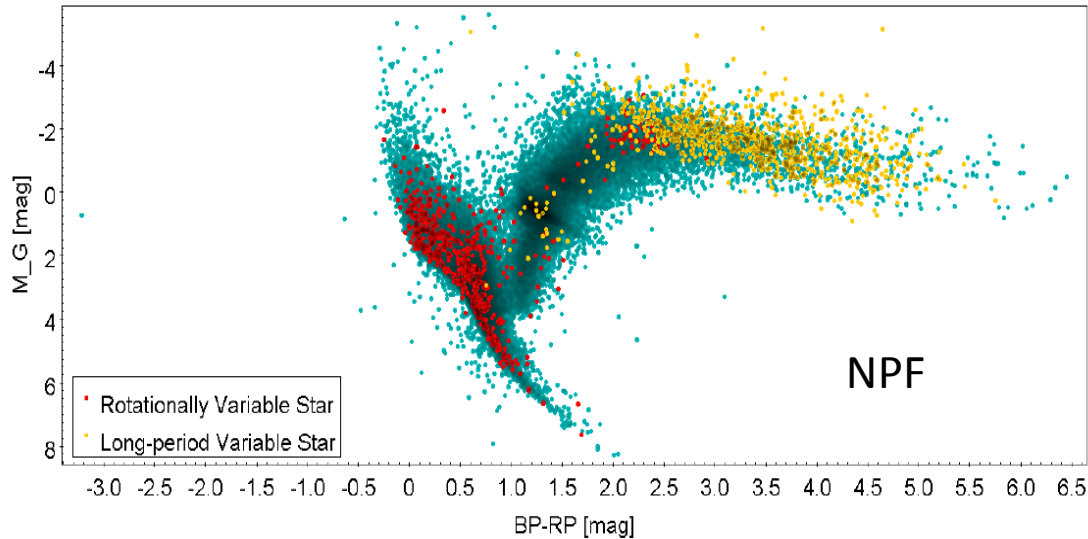Relative G Flux error

54 μas

51 μas

10 %

5 %

Variability

NPF

Rotationally Variable Star
Long-period Variable Star
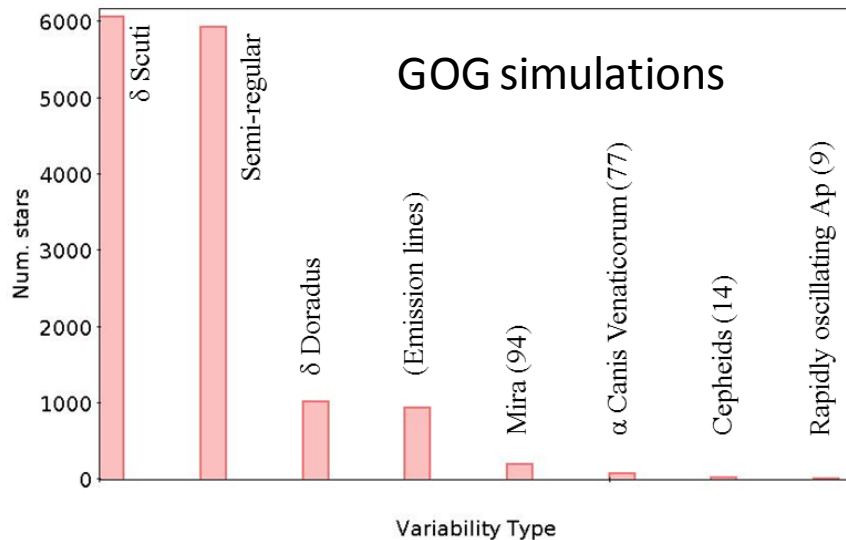

GOG simulations

Type	NPF	SPF
Variable	755	533
Not Available	71623	67783

Gaia-DR2 flag

Variability is not available in Gaia-DR2.
GOG simulations are still needed.

| Type	NPF	SPF
Rotationally Variable Star	584	98
Long-period Variable Star	581	127
Variable Star	433	148
Variable of delta Sct type	208	35
Variable of Mira Cet type	107	56
Eclipsing binary	192	93
Pulsating Variable Star	58	19

Simbad flag

MULTIPLICITY

112 570 stars in double or multiple systems (60%), according to GOG simulations

Close sources in Gaia-DR2 (both PLATO fields)
- **2990 in 1 PLATO pixel = 15 arcsec**
- **7485 in 3 PLATO pixels = 77% of the flux, 45 arcsec**
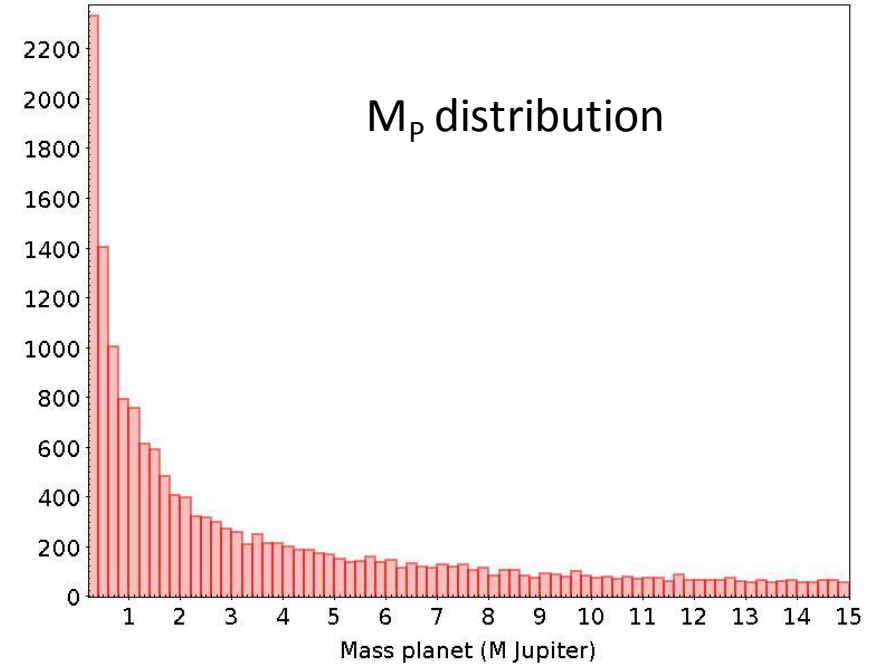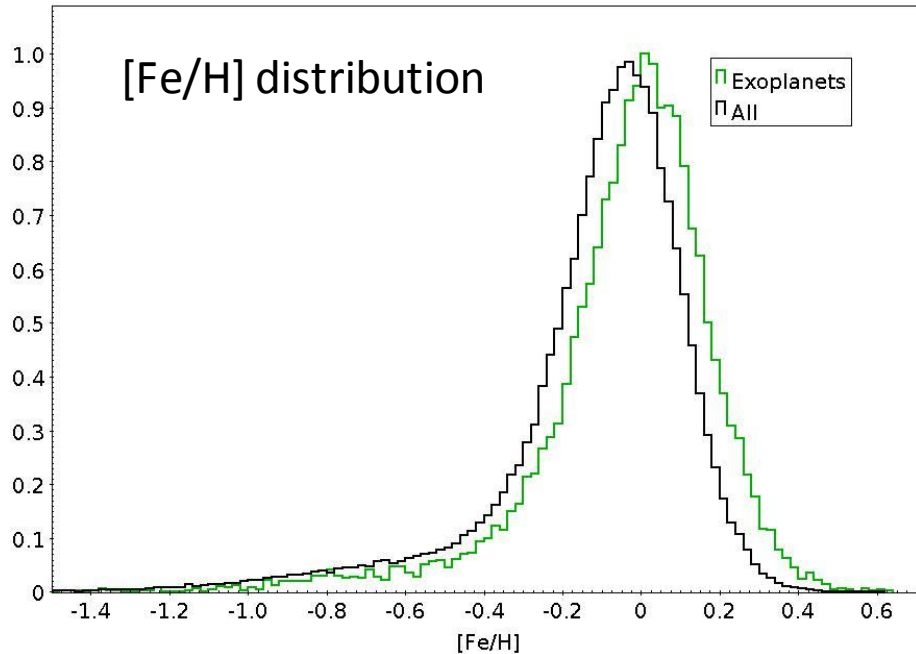- **15240 in 5 PLATO pixels = 99% of the flux, 75 arcsec**

Gaia can resolve closer sources than PLATO. Reject them as PLATO targets.

1 pixel **3 pixels** **5 pixels**

(Gaia-DR2 data)
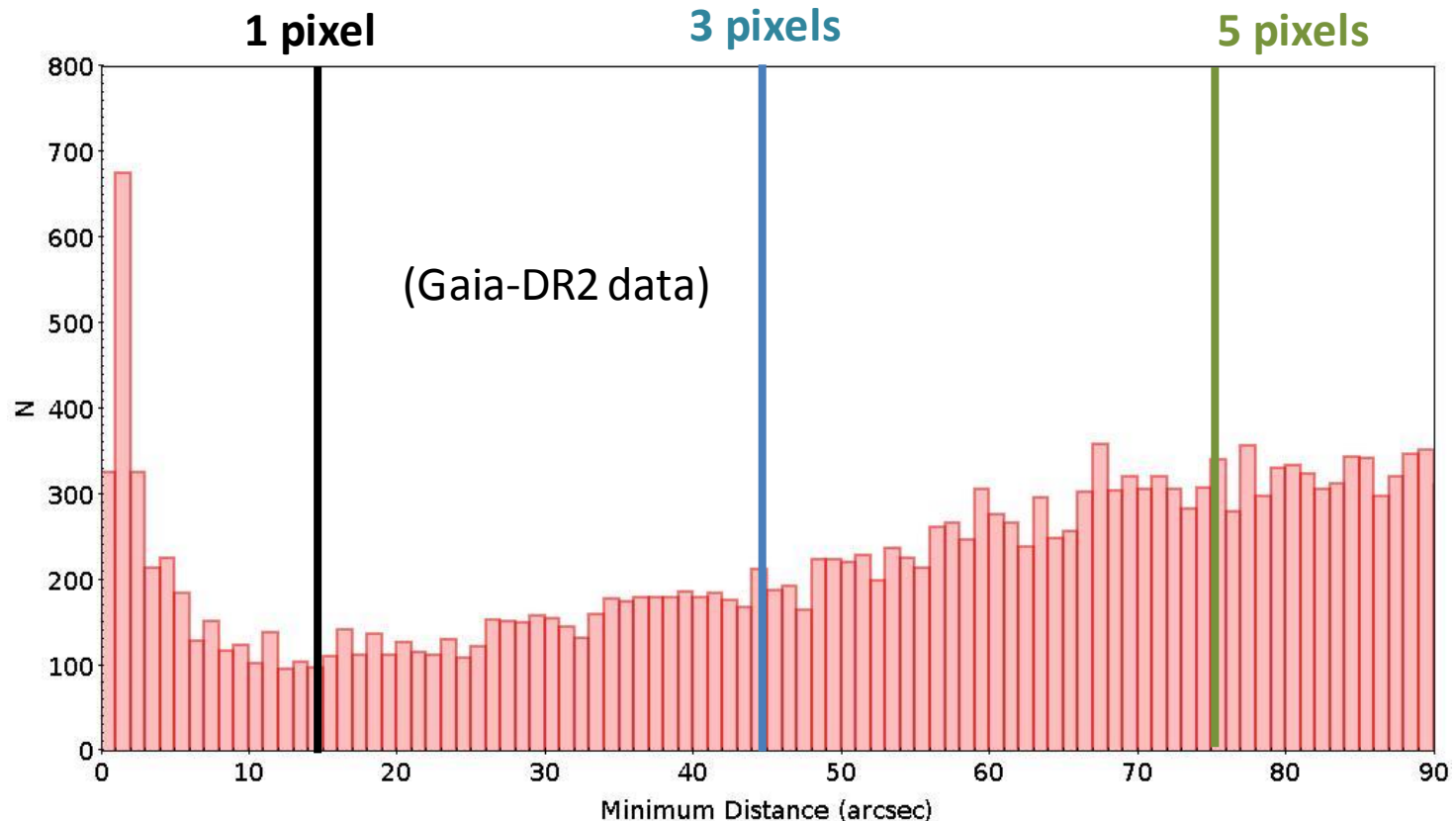
Exoplanets (GOG)

- Probability of hosting a planet = f([Fe/H])   Prob. < 0.5

- Probability of having a planet of mass M_P is $\alpha\, e^{-Mp}$ with $0.2M_J < M_P < 15M_J$ (M_J = Jupiter mass).

- Planet radi (R_P) => $R_P = F(M_P) = \sum_i a_i M_P^i$

- 16500 exoplanets in PLATO fields simulations

All these assumptions can be modified according to your suggestions

For more details see:
Robin et al. 2018, A&A 543, A100 ; Sozzetti, Torres, Latham, 2009, ApJ, 697, 544

THANK YOU

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