



# **Mephisto: Photometric Calibration with Improved Gaia XP Synthetic Photometry Method**

**Mephisto巡天流量定标：基于XP光谱的光度合成方法**

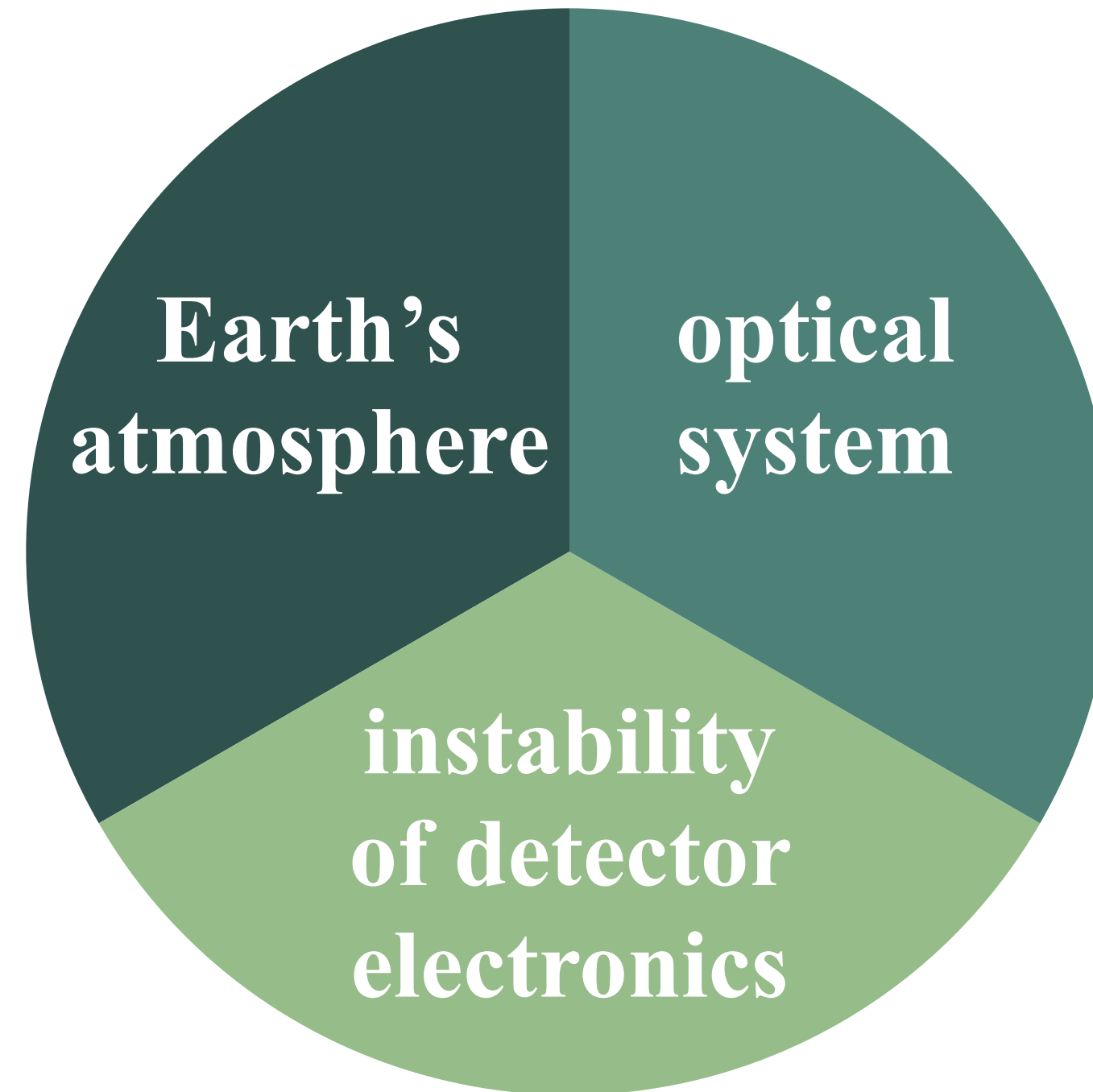
张敬华

参与者：梦飞团组；苑海波；肖凯；向茂盛；黄博闻 等

2024.08.04 @ 银河系及近邻星系时域研讨会

$$m = m_{\text{ADU}} + \boxed{ZPT(t, X, Y, m, \text{color})}$$

**rapid changes in the Earth's atmospheric transparency on temporal spans of seconds to minutes**



**difficulty in accurately correcting the flat fields**

**gain variation**

# Background



imaging survey	(re)calibration precision	ref.	Method
SDSS	0.01 - 0.02 mag	Padmanabhan et al. 2008	Uber-calibration
Pan-STARRS DR1	~0.01 mag	Schlafly et al. 2012	Uber-calibration
BASS	< 0.01mag	Zhou et al. 2018	Uber-calibration
Gaia	~1 mmag	Abbott et al. 2021	Uber-calibration
Pan-STARRS DR1	7 - 9 mmag	Finkbeiner et al. 2016	Hyper-calibration
DES	< 3.6 mmag	Huang et al. 2022	FGCM
J-PLUS DR3	~ 0.01 mag	Lopes-Sanjuan et al. 2021	SL
SDSS	2 - 5 mmag	Huang et al. 2022	SCR
SkyMapper	5 - 10 mmag	Huang et al. 2021	SCR
J-PLUS DR3	1 - 5 mmag	Xiao et al. 2023	SCR

### Gaia DR3 XP spectra

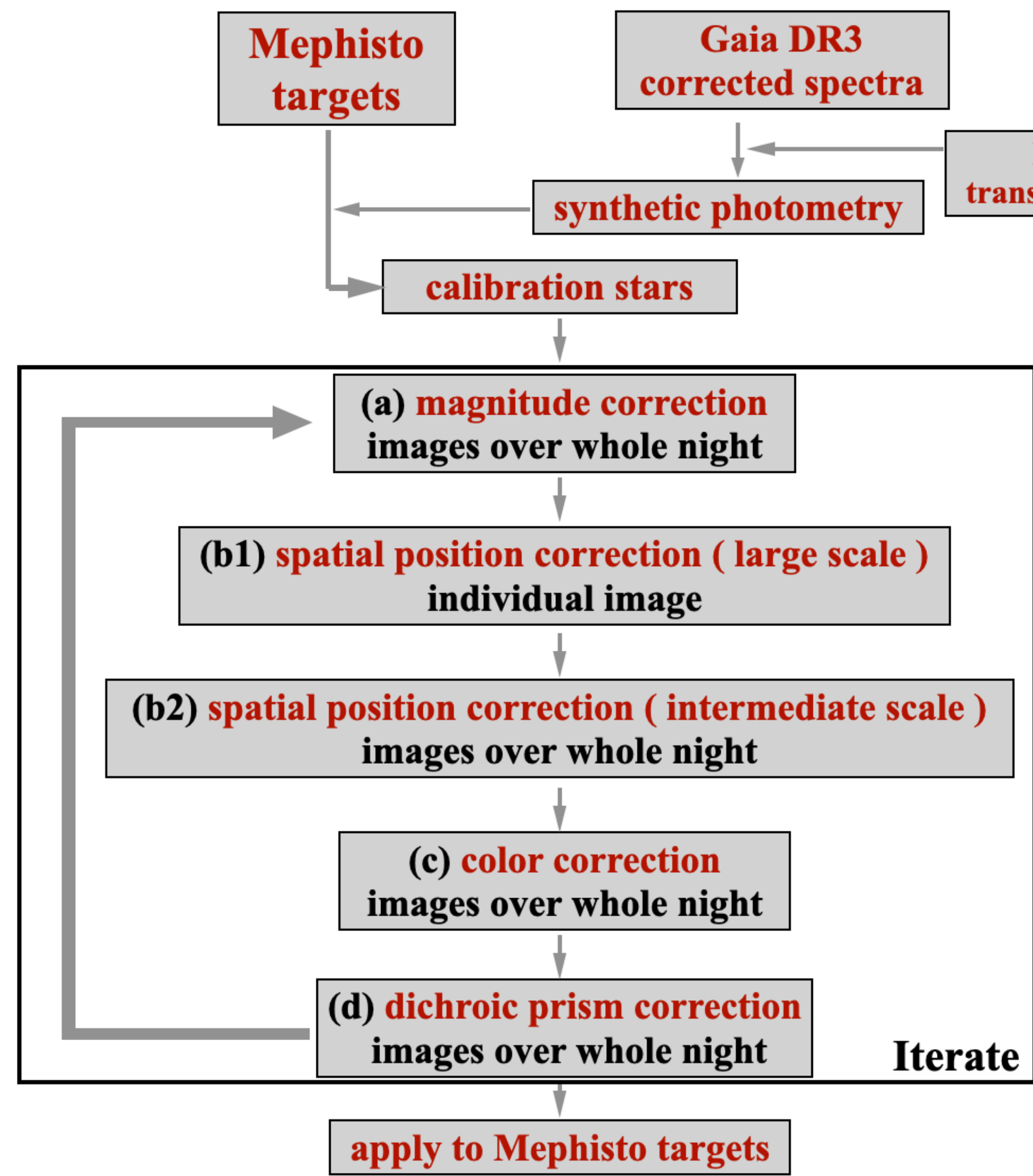
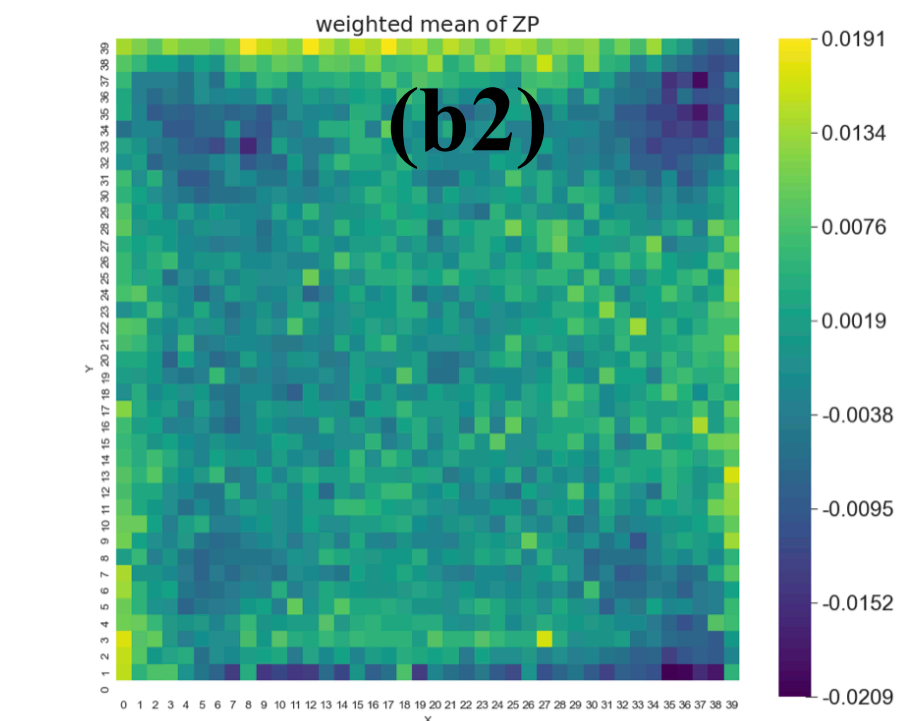
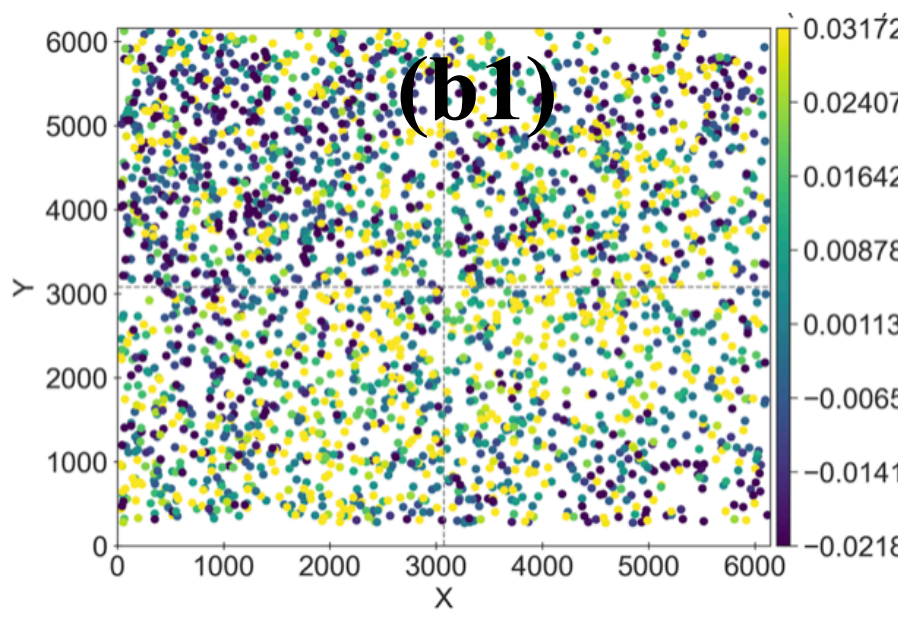
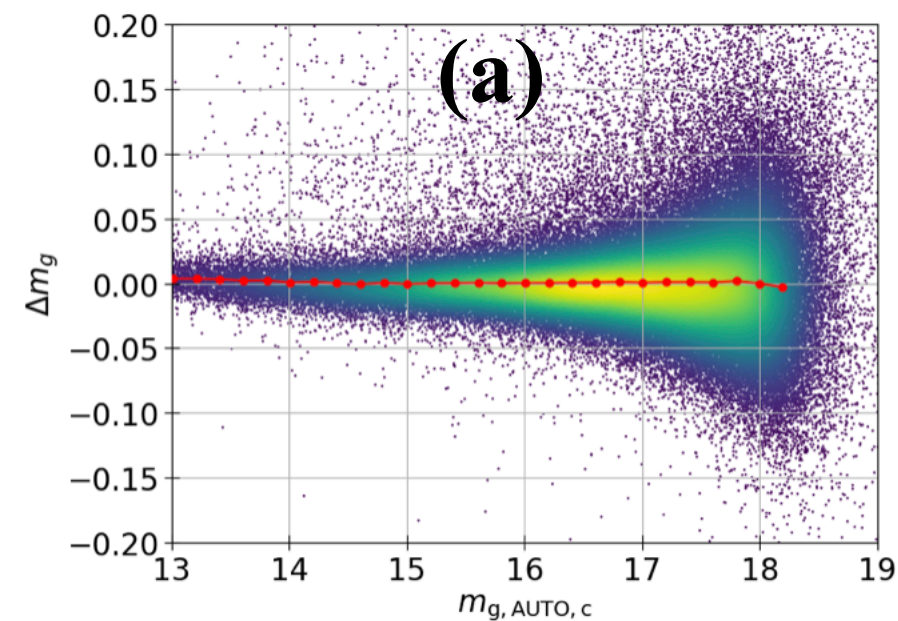
- ◆ 220 million, all-sky
- ◆ 336-1020 nm,  $\lambda/\Delta\lambda \sim 20\sim 70$
- ◆  $G < 17.65$  mag

$$m_{\text{XPSP}} = -2.5 \lg \frac{\int_x f_\lambda(\lambda) S(\lambda) \lambda d\lambda}{c \int_x S(\lambda) \lambda^{-1} d\lambda} - 48.60$$

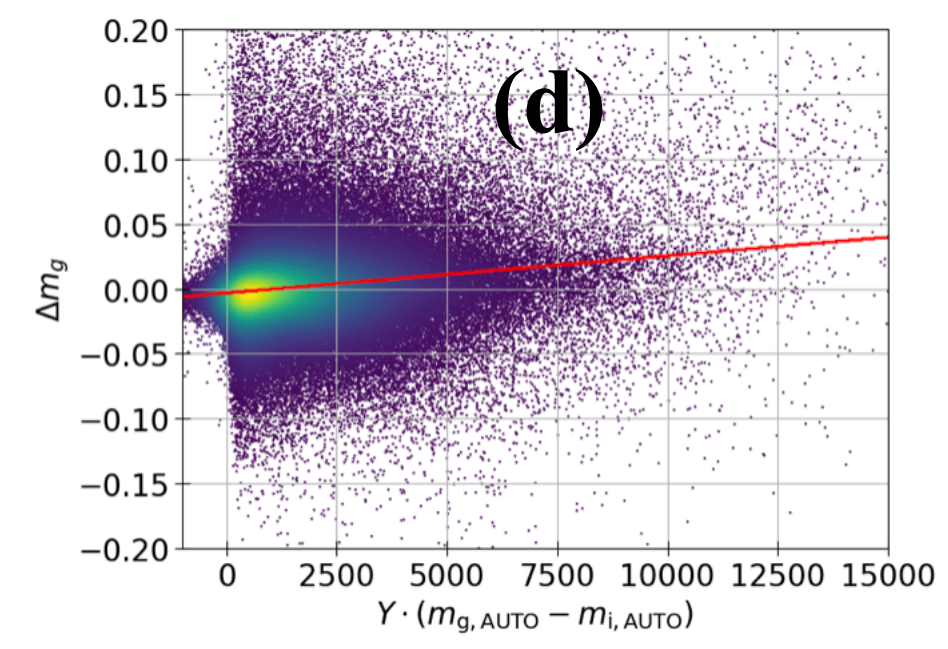
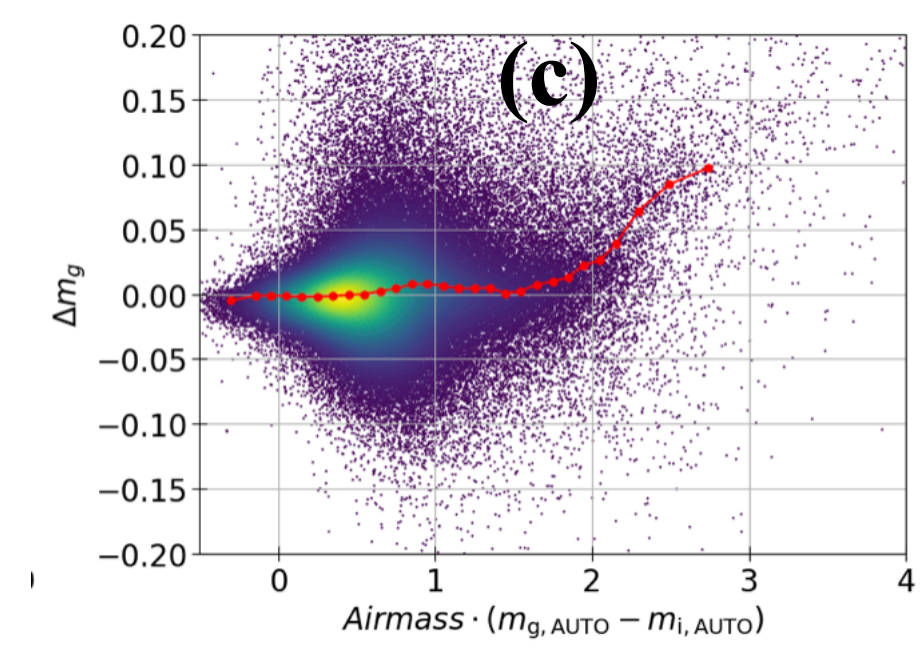
$f_\lambda(\lambda)$  the Gaia XP spectra;  
 $S(\lambda)$  the transmission curve.

imaging survey	(re)calibration precision	ref.
Pan-STARRS DR1 (America)	1-2 mmag	Xiao et al. 2023a
SAGES g/r/i (China)	1-2 mmag	Xiao et al. 2023b
J-PLUS DR3 (Spain)	1-5 mmag	Xiao et al. 2023c Lopes-Sanjuan, Xiao, et al. 2023
S-PLUS DR4 (Brazil)	1-5 mmag	Xiao et al. 2024

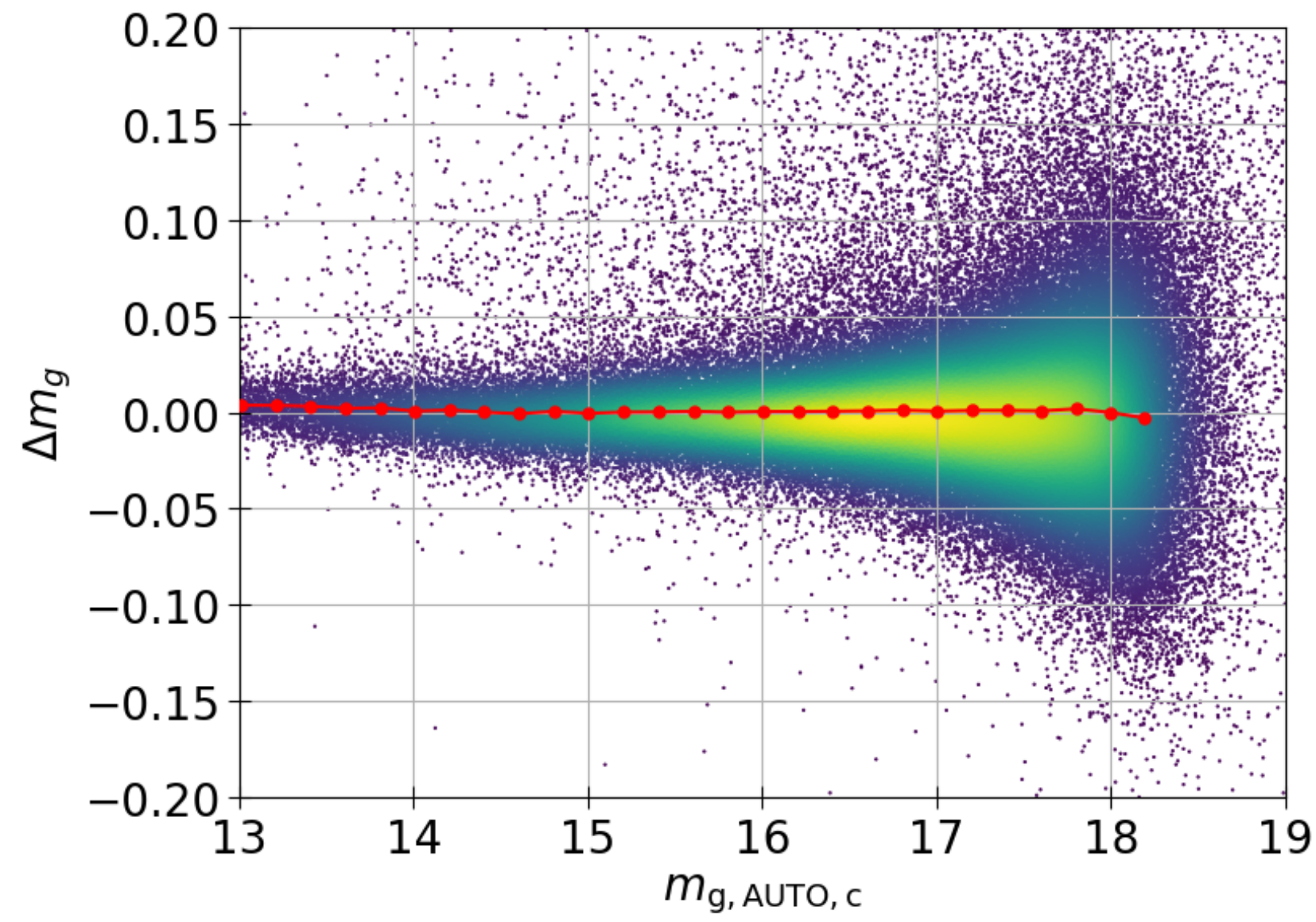
# Flowchart



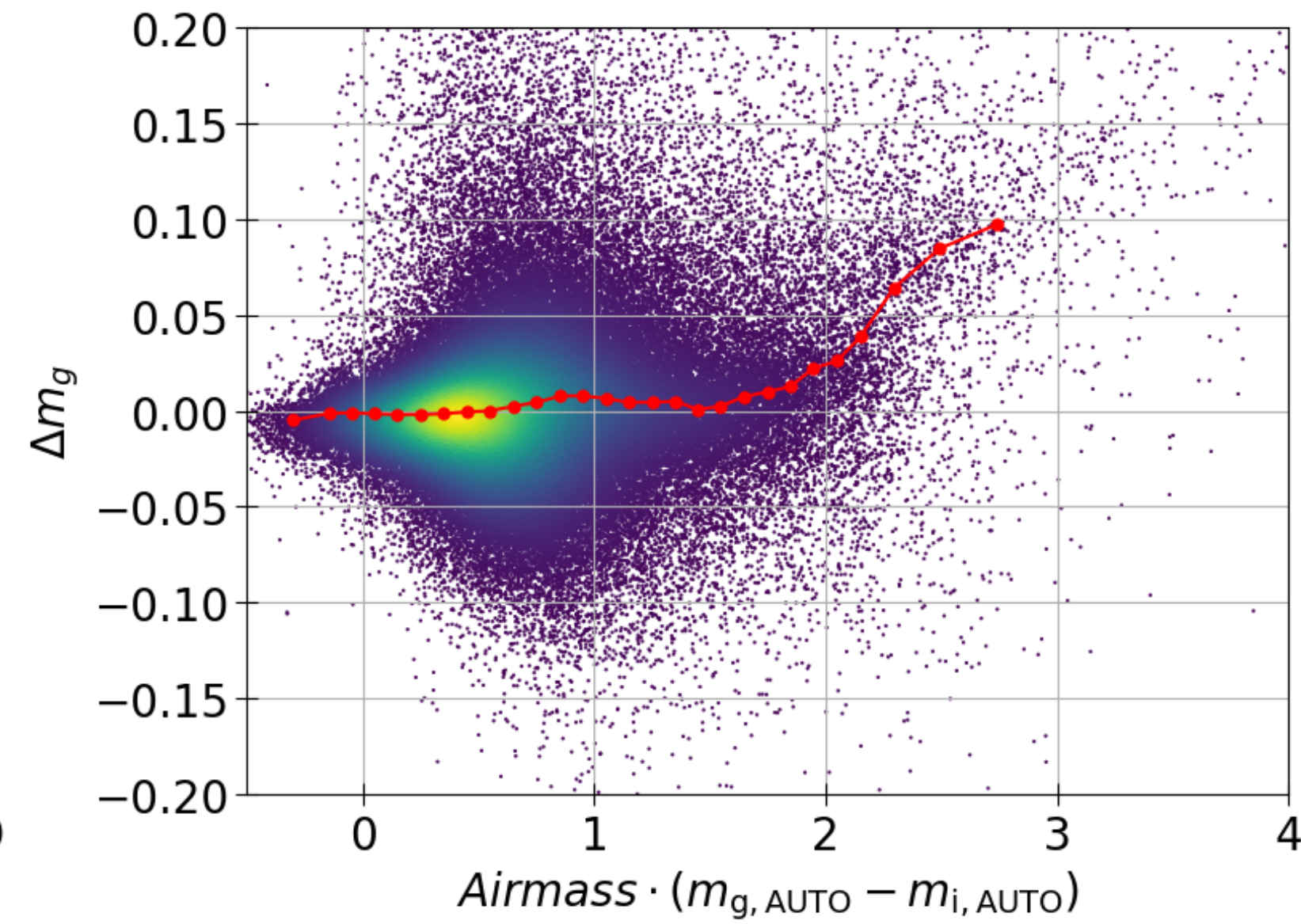
Mephisto transmission curve



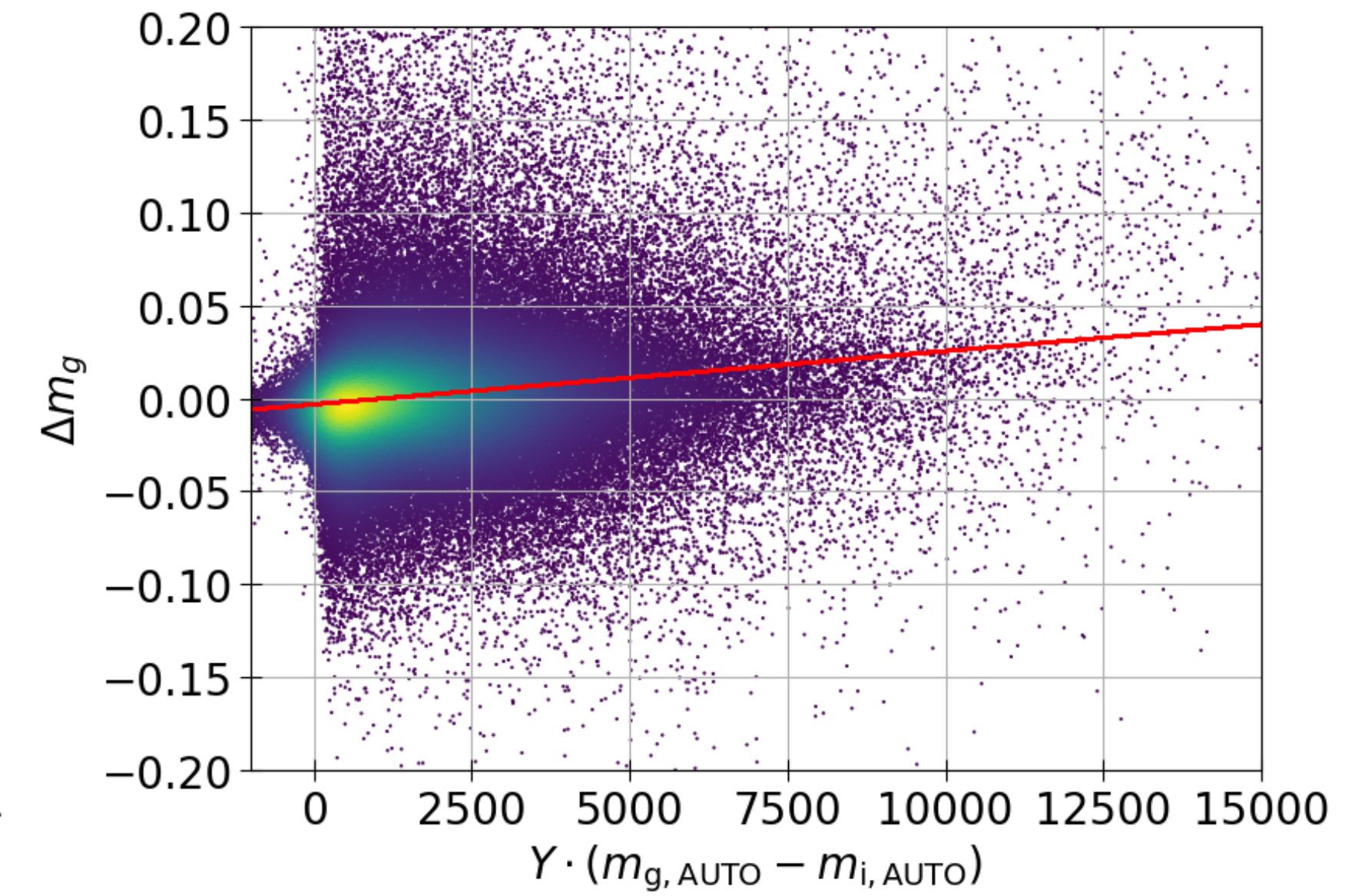
### Magnitude



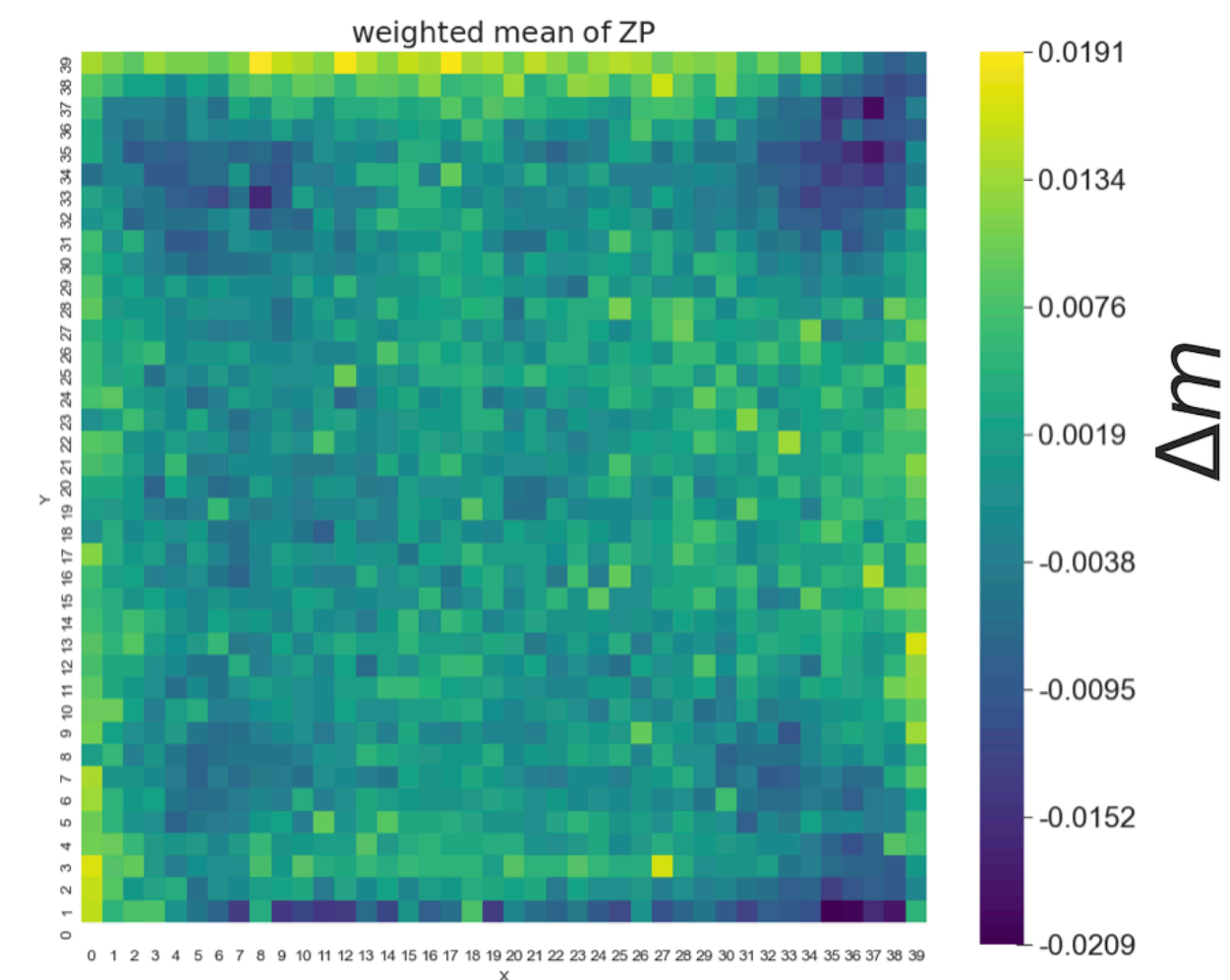
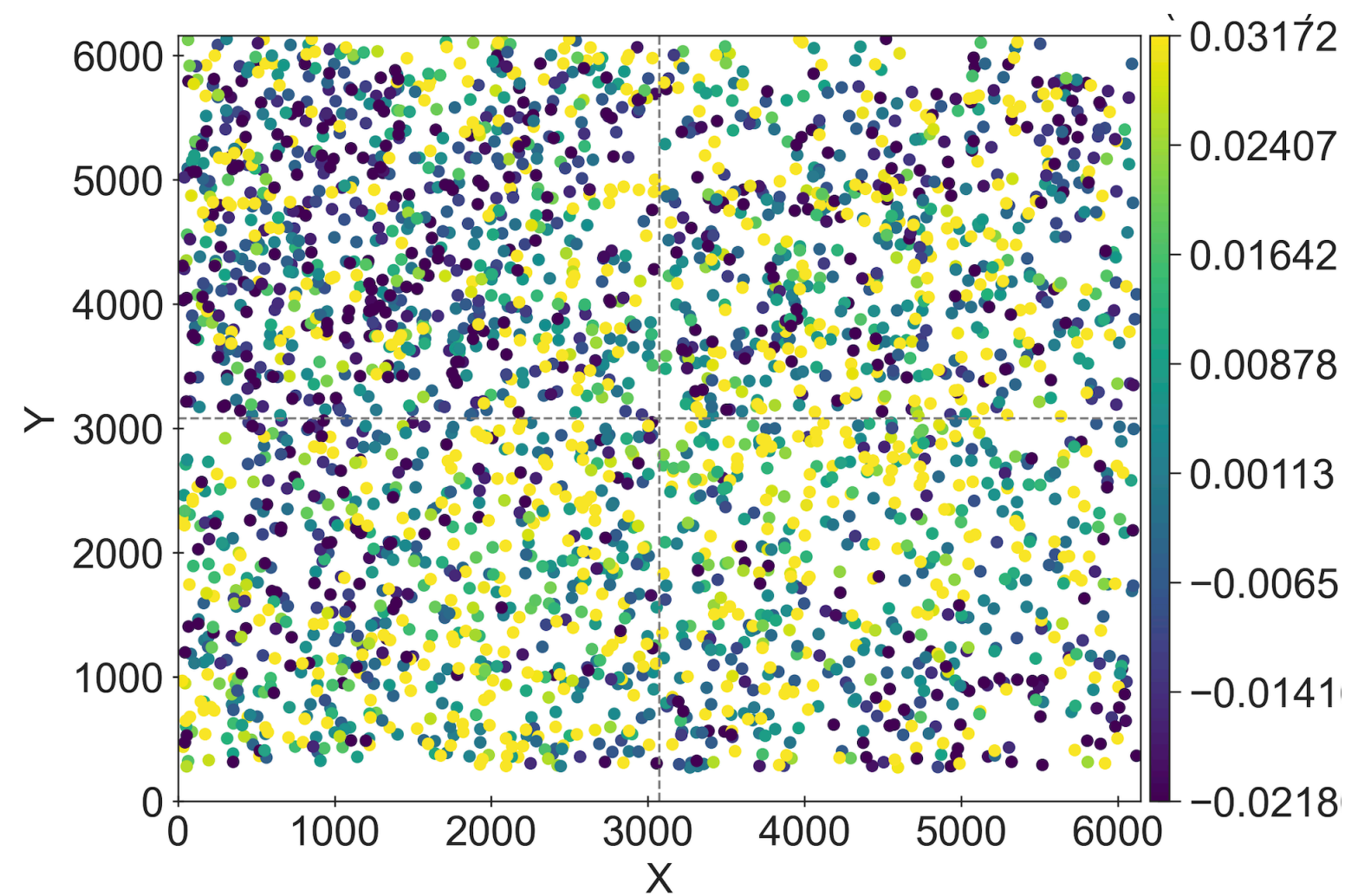
### Color



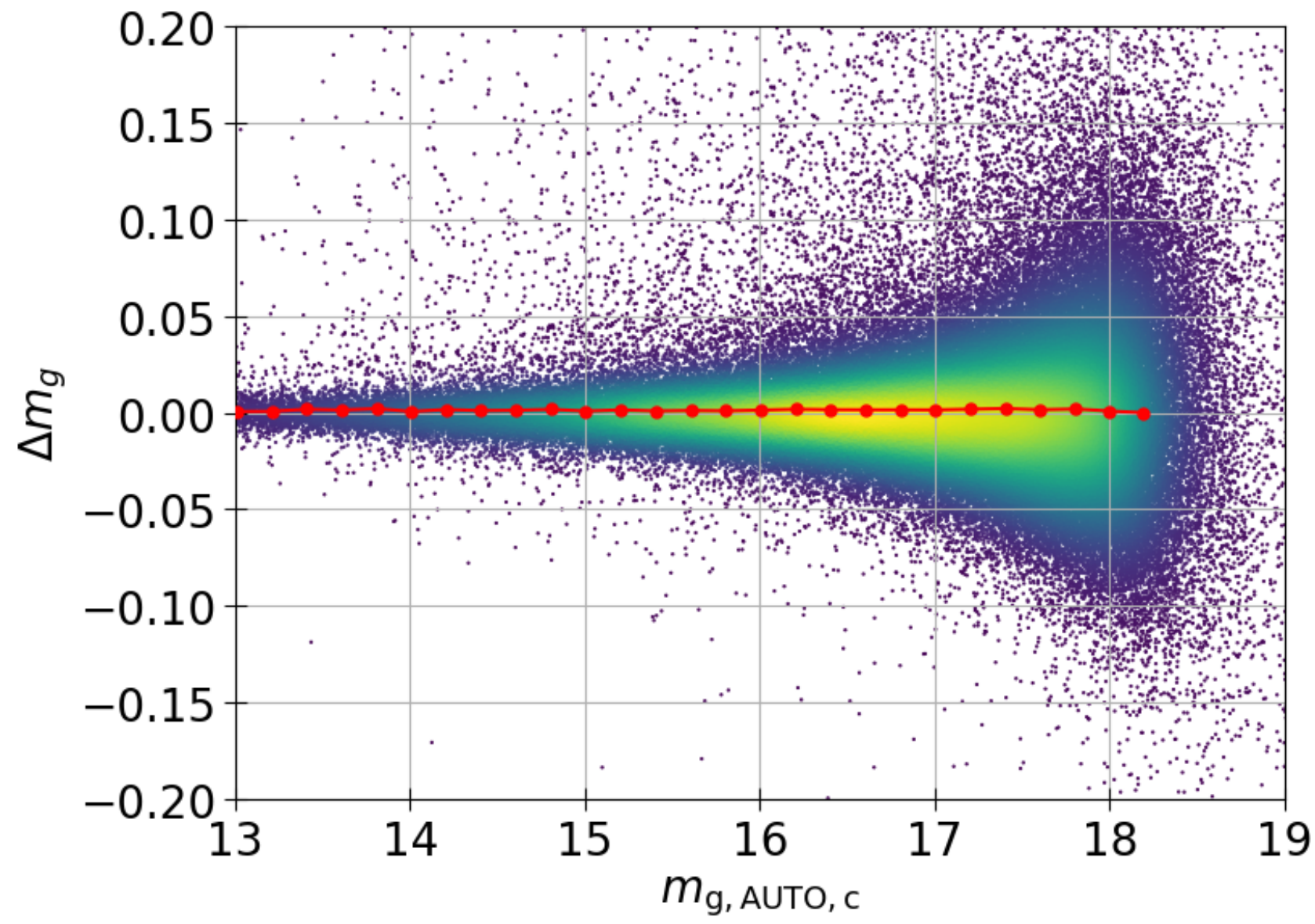
### Dichroic



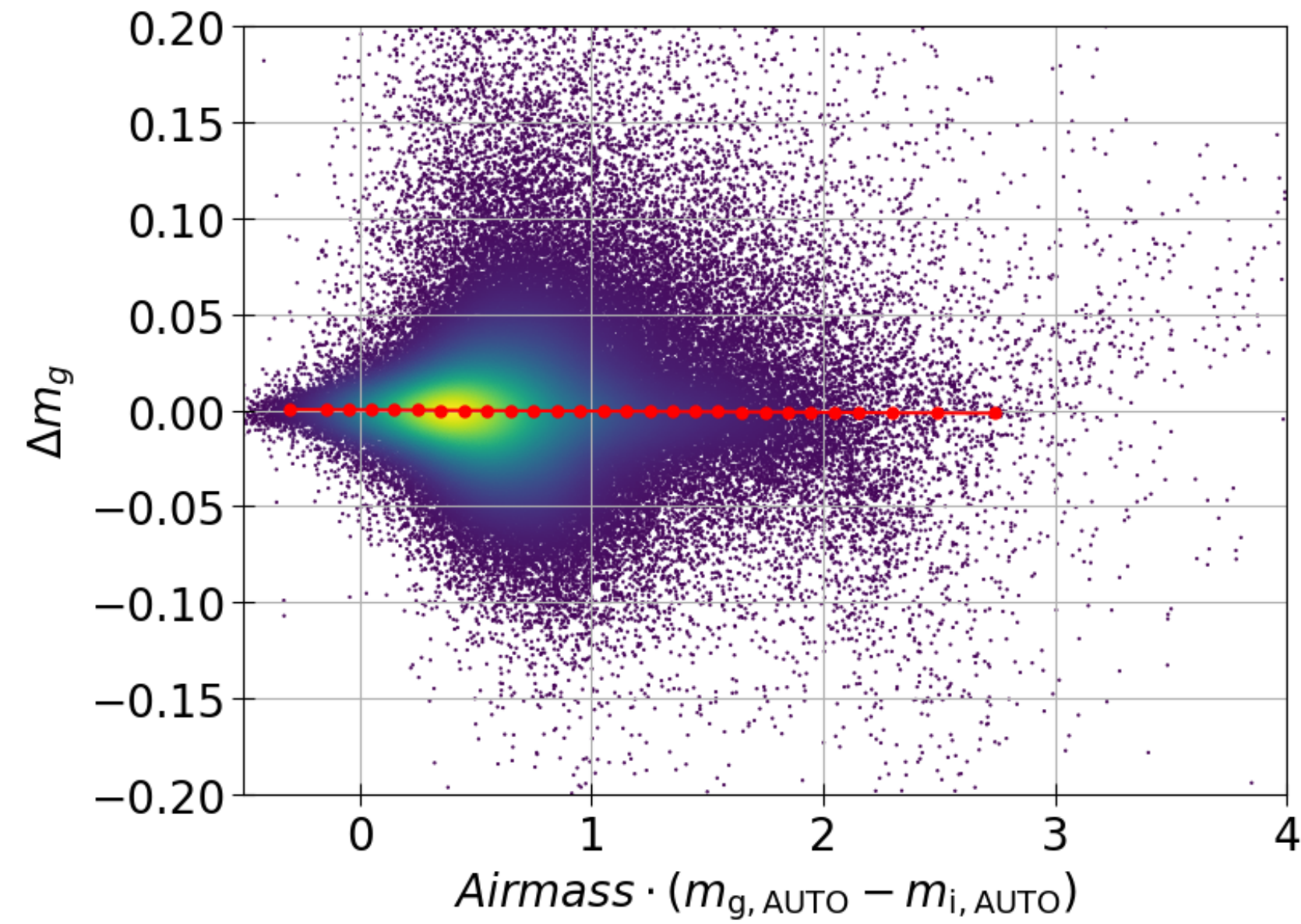
### space



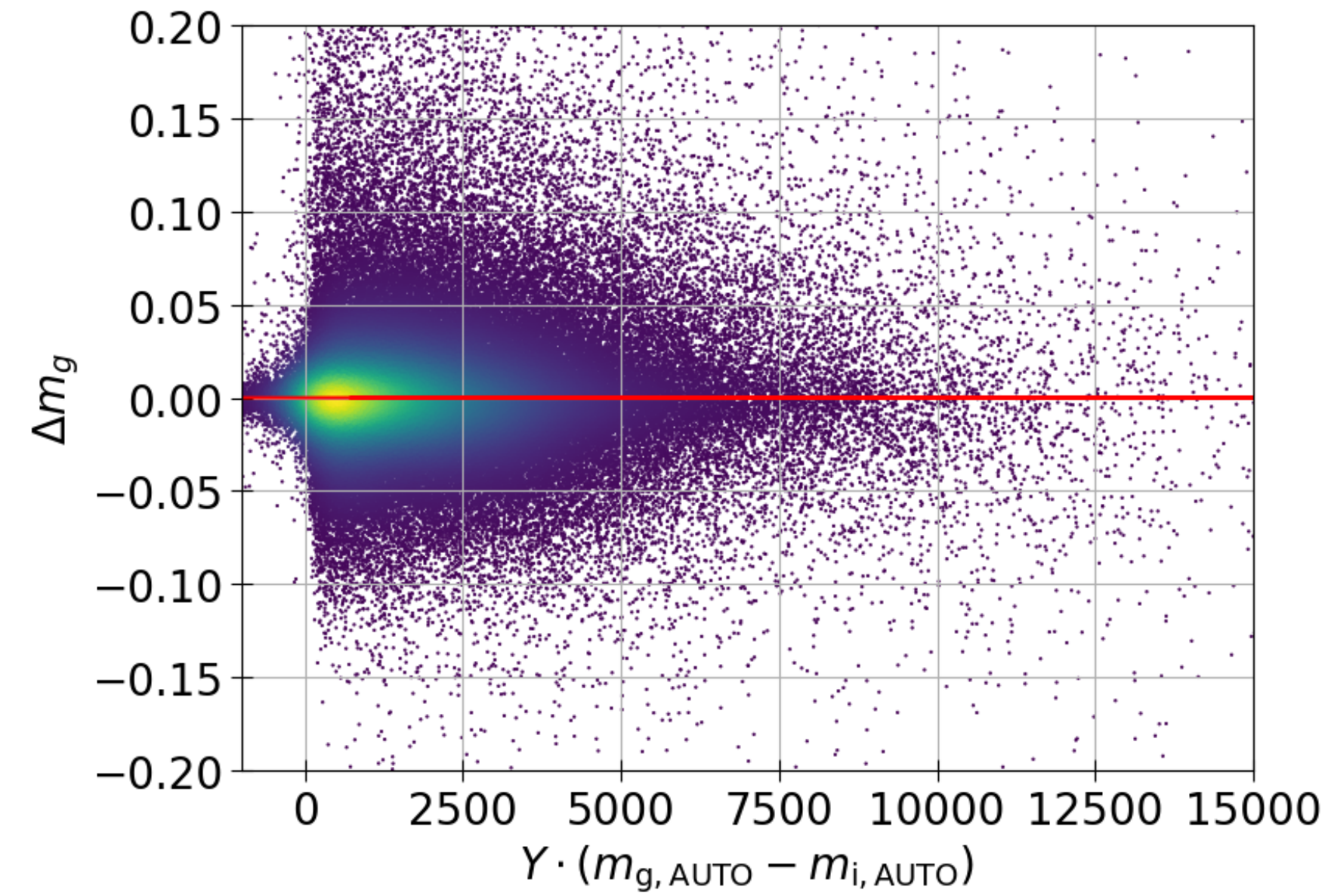
### Magnitude



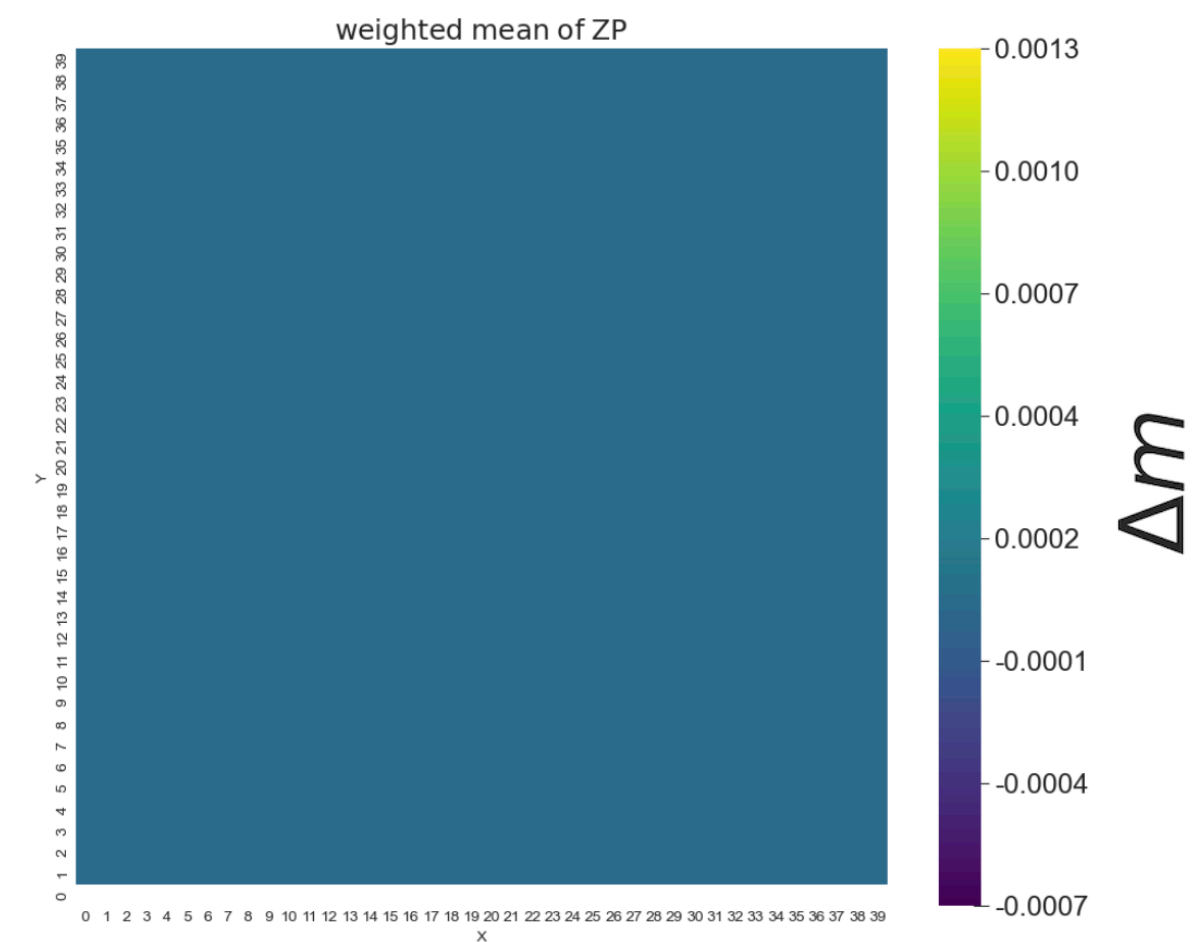
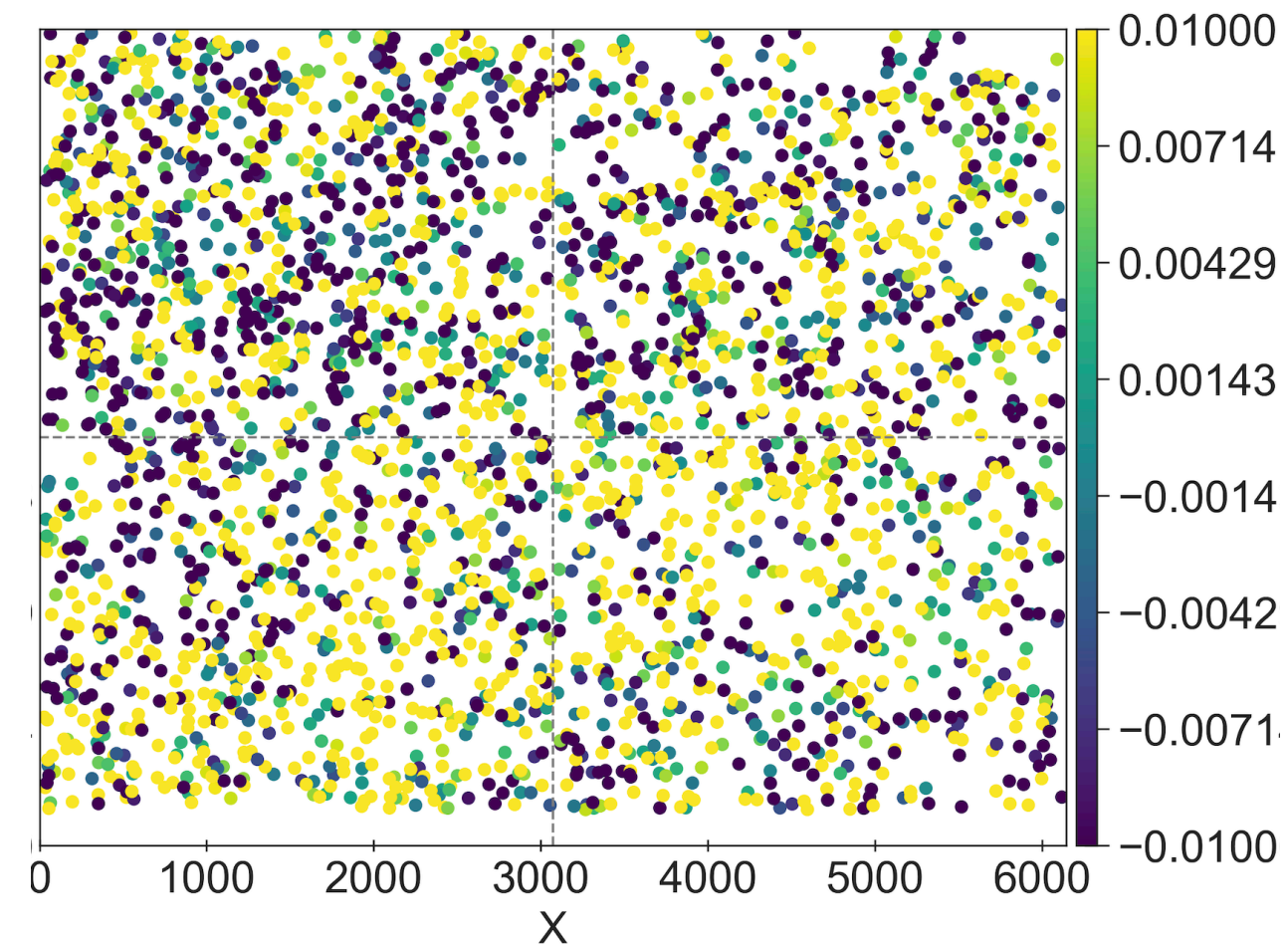
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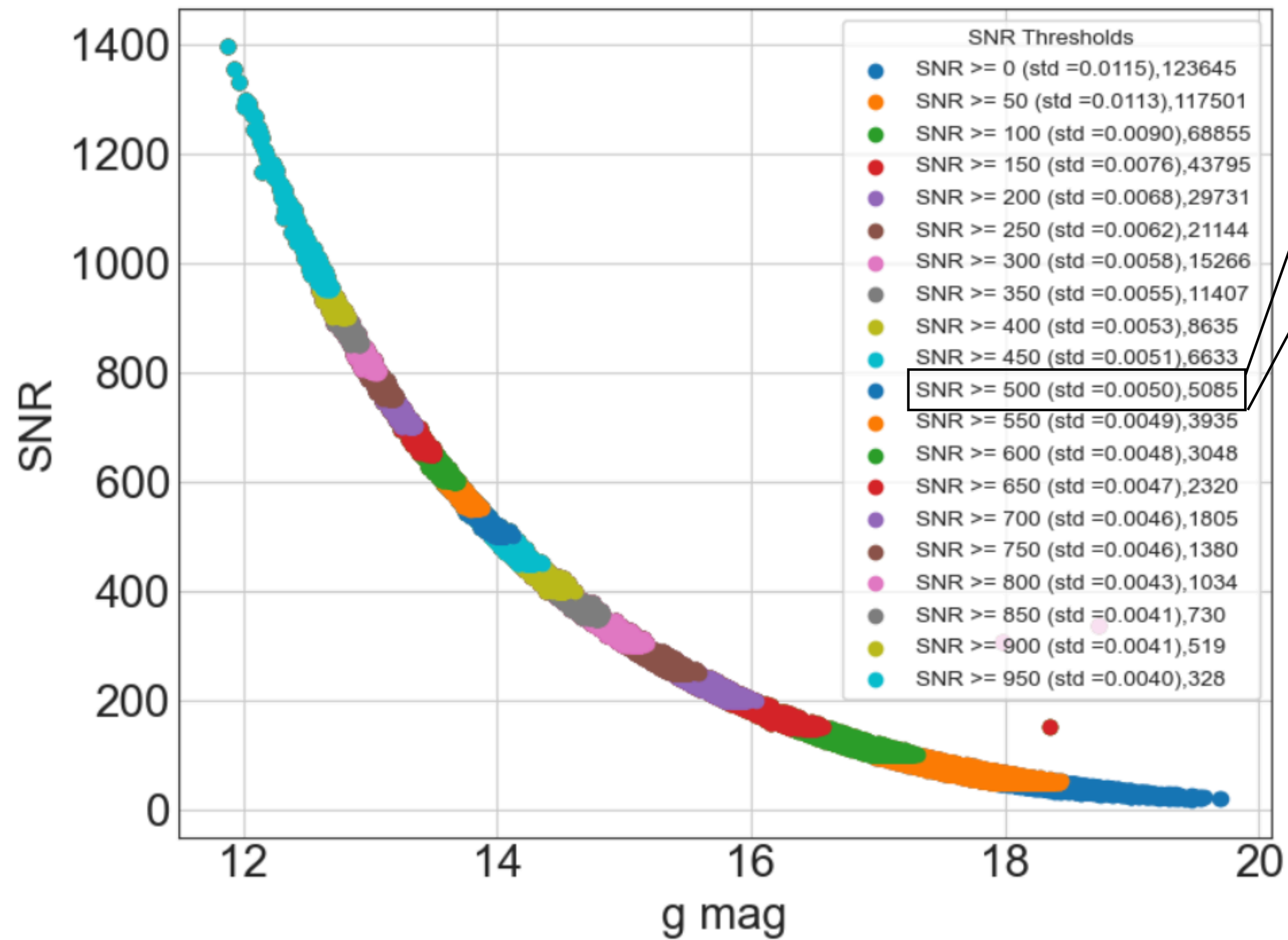


### Dichroic



### space





SNR >= 500 (std =0.0050),

**The Gaia XP Synthetic photometry Method achieved a precision of 5mmag for stars with SNR > 500.**

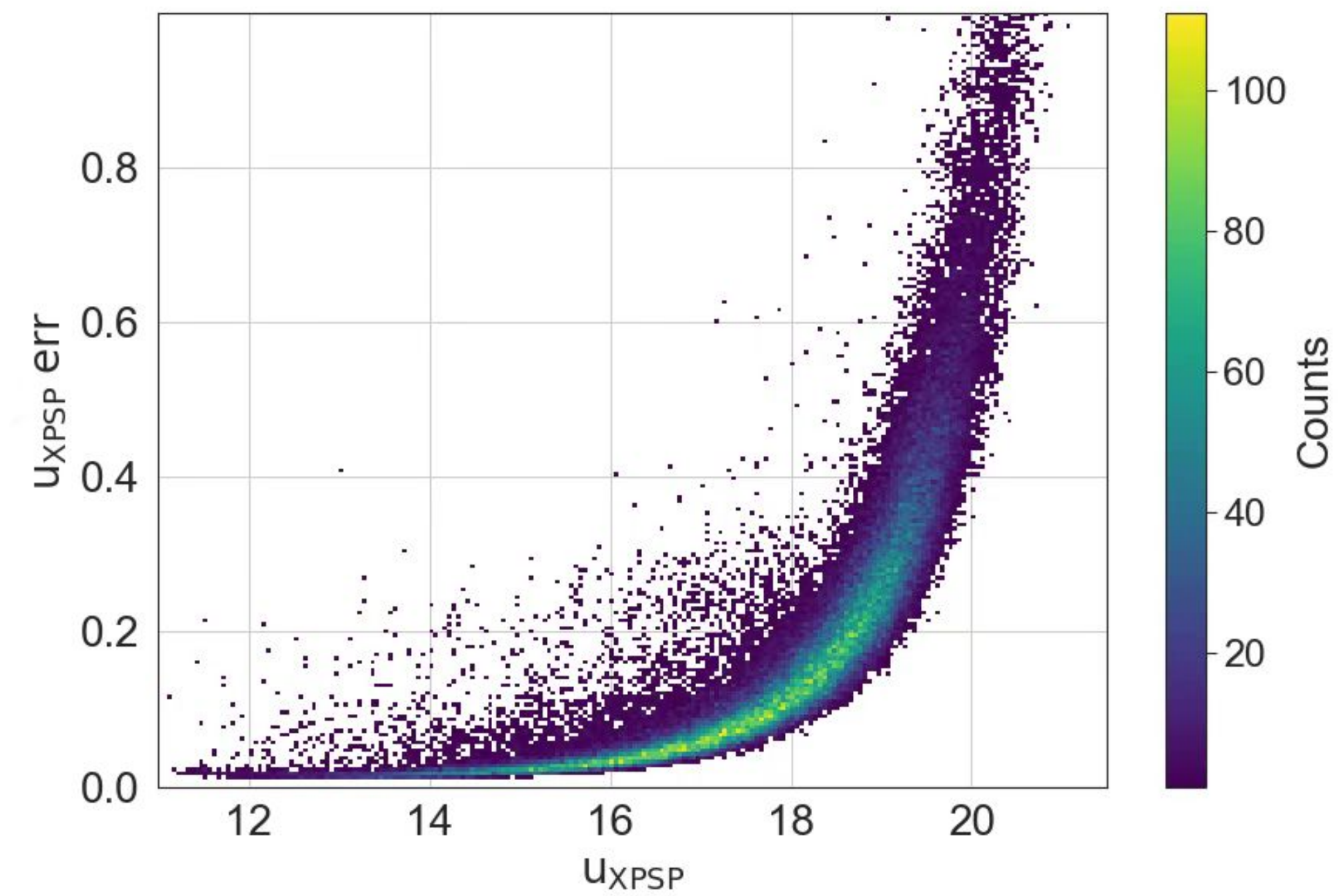
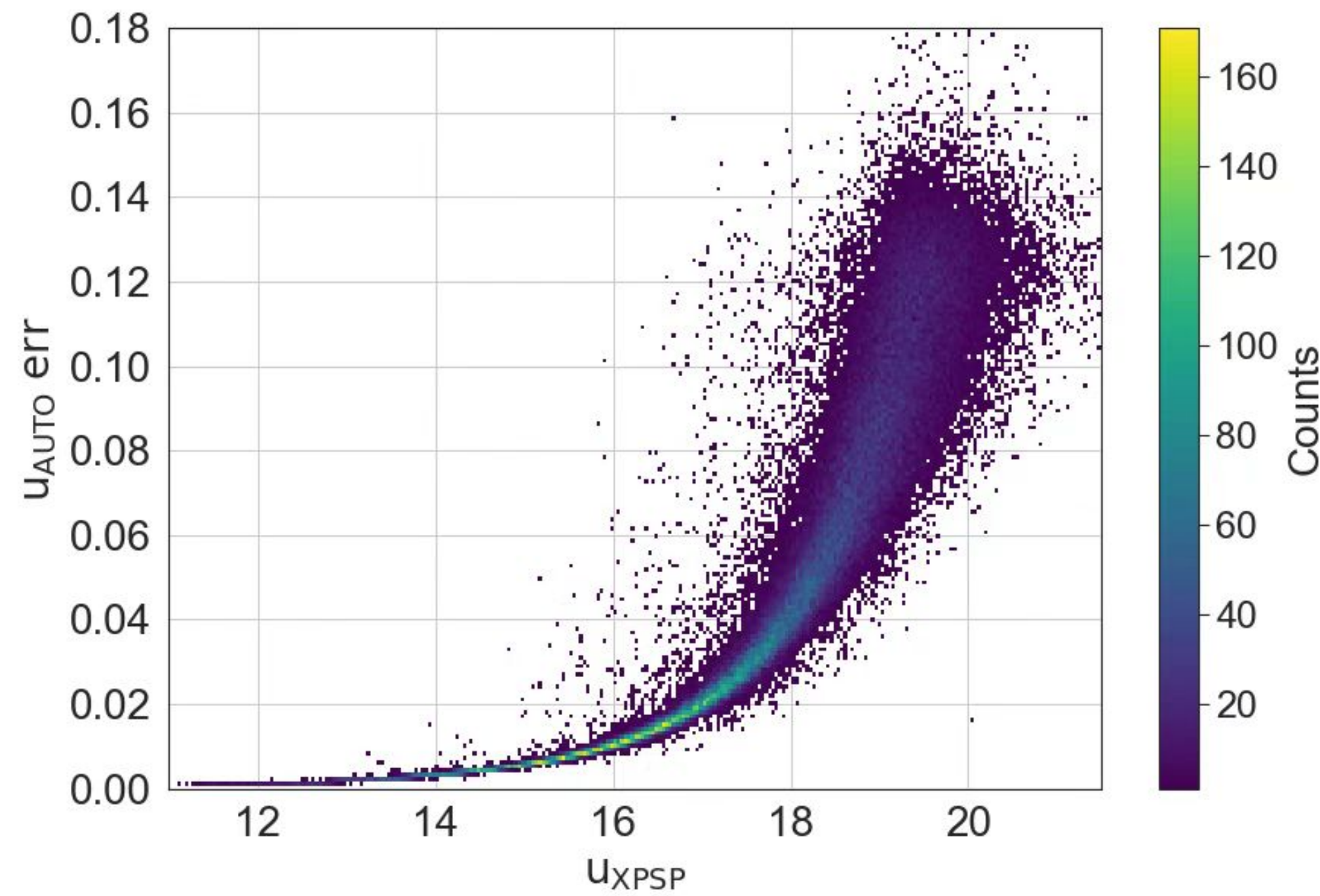


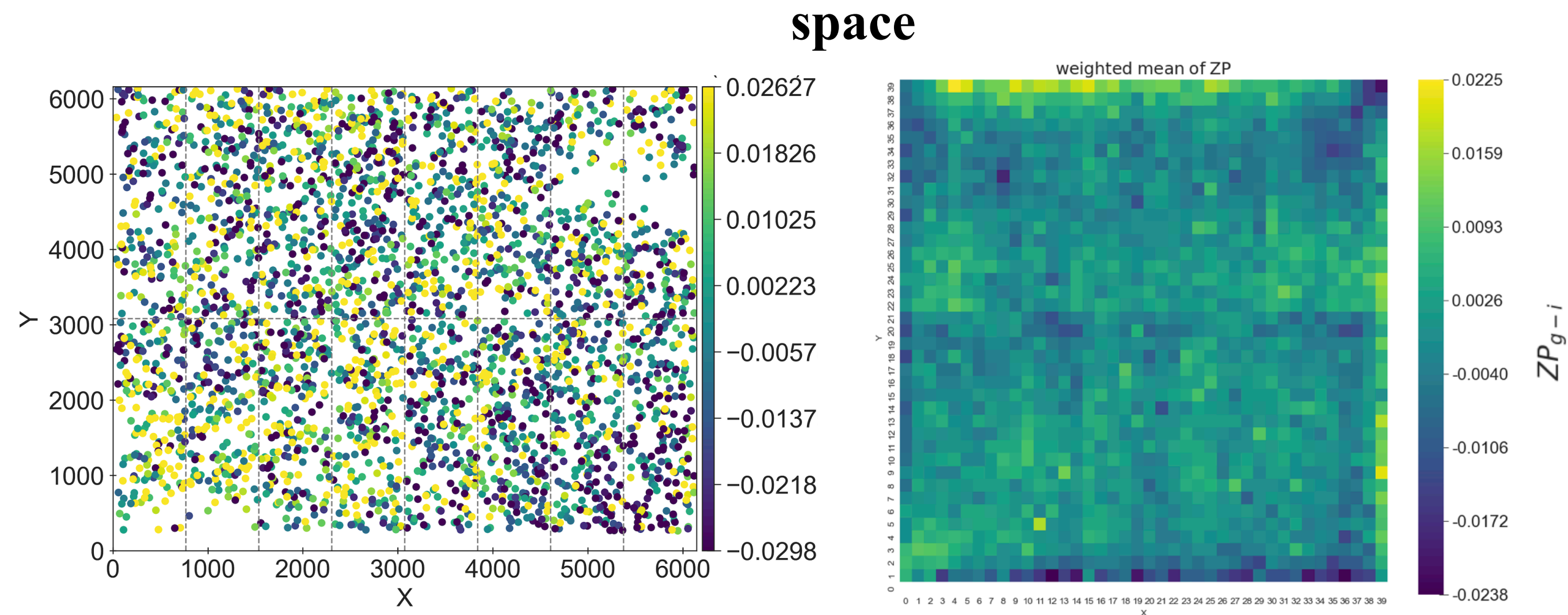
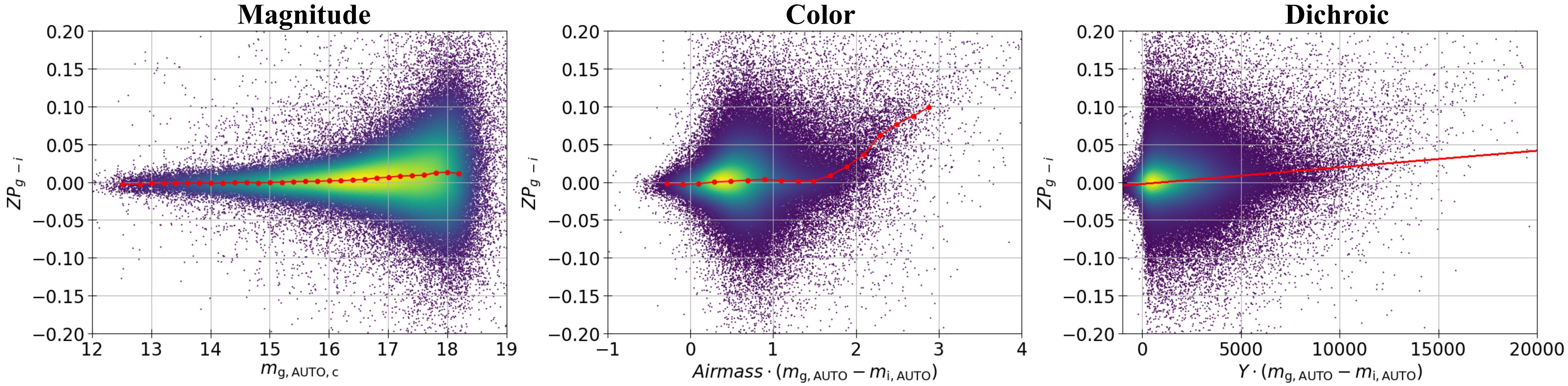
# Calibration precision

Bands	ZP precision (SNR)
u	0.031 (300)
v	0.011 (300)
g	0.005 (500)
r	0.005 (500)
i	0.005 (400)
z	0.006 (500)

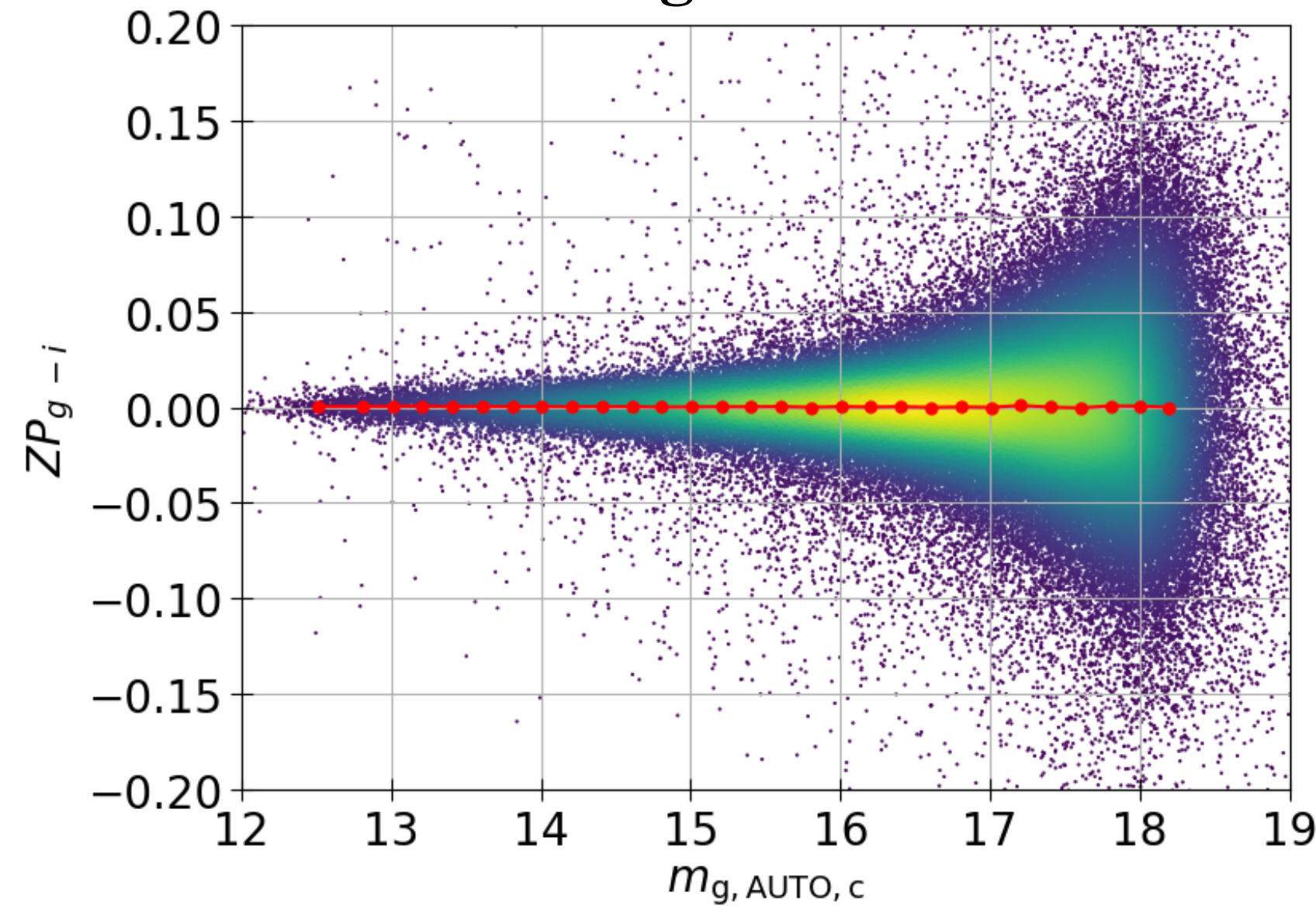
# Calibration precision

Bands	ZP precision (SNR)
u	0.031 (300)

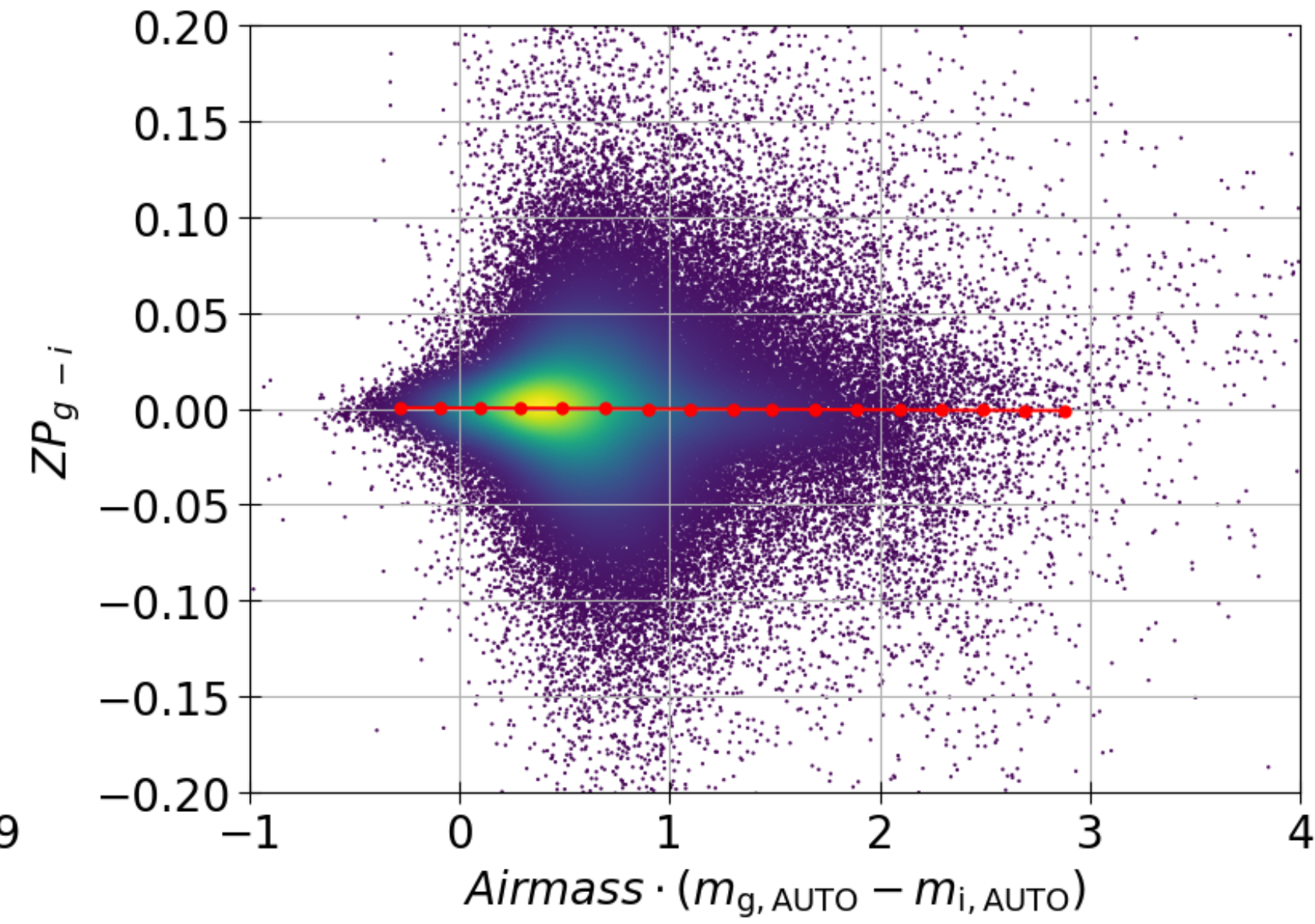




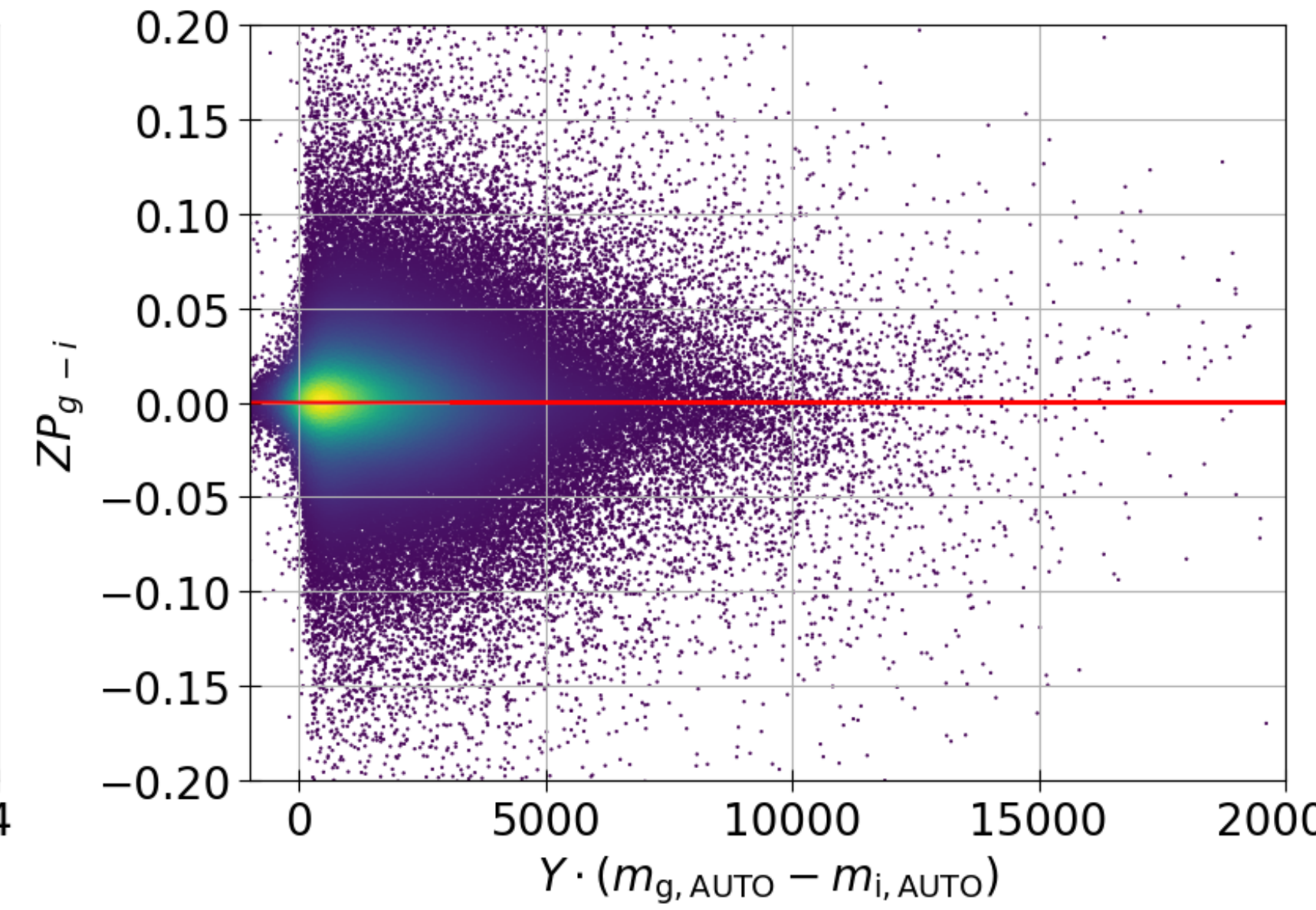
### Magnitude



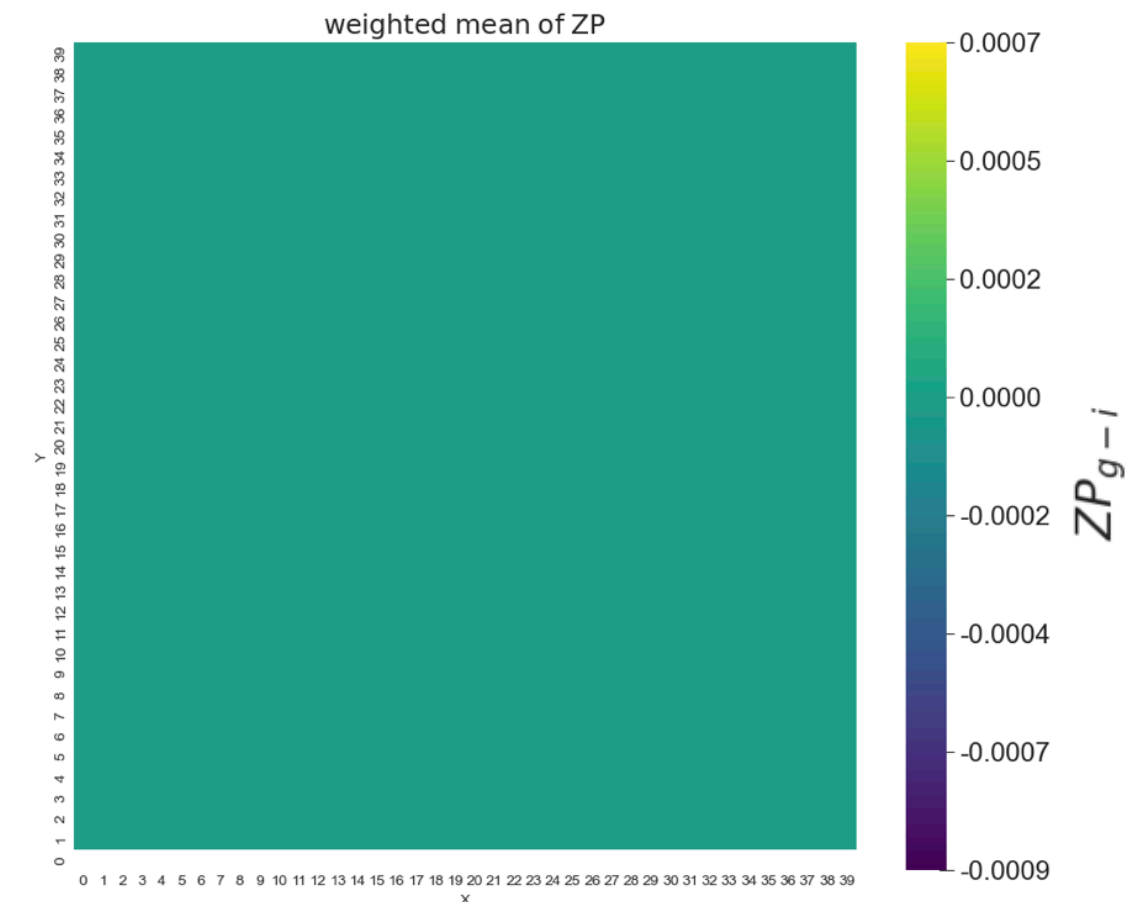
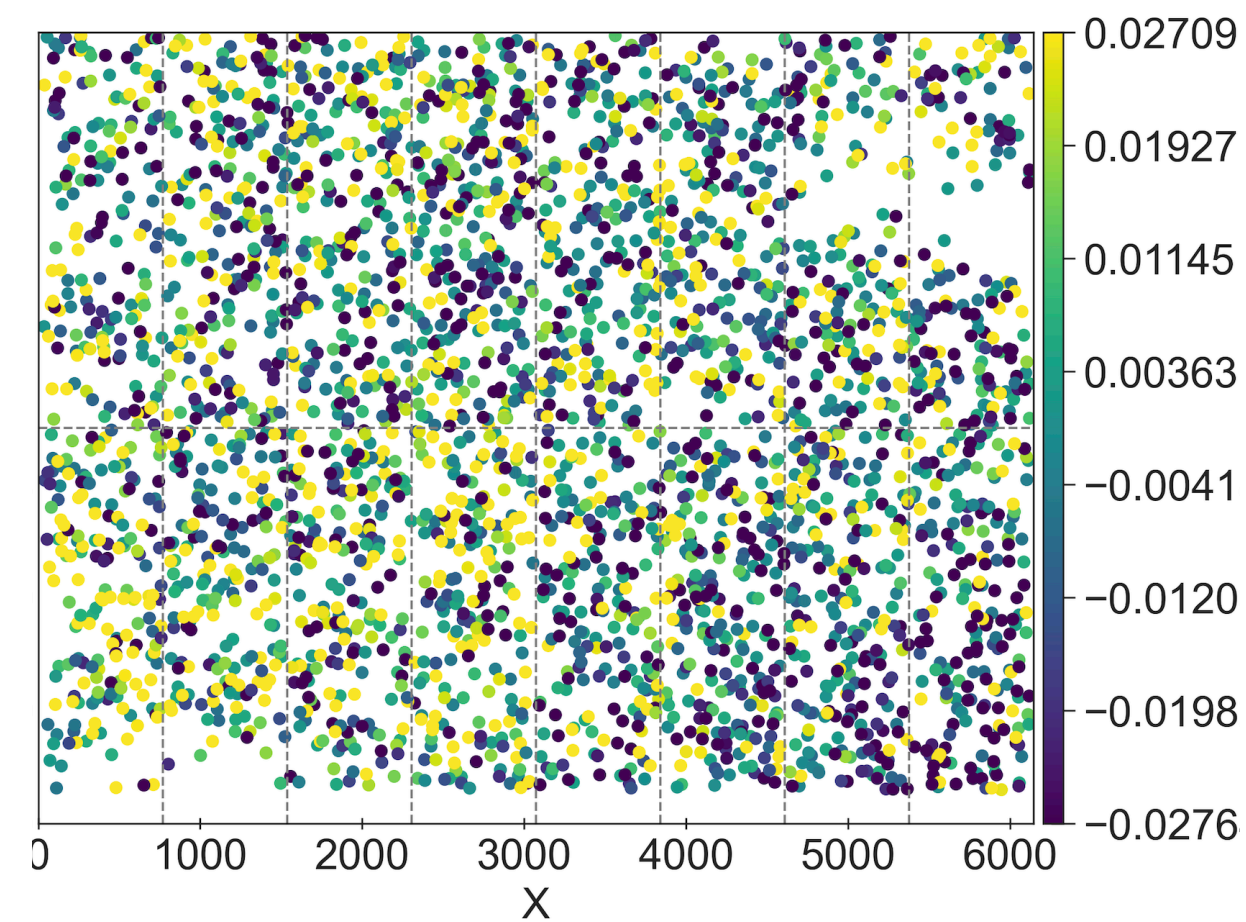
### Color

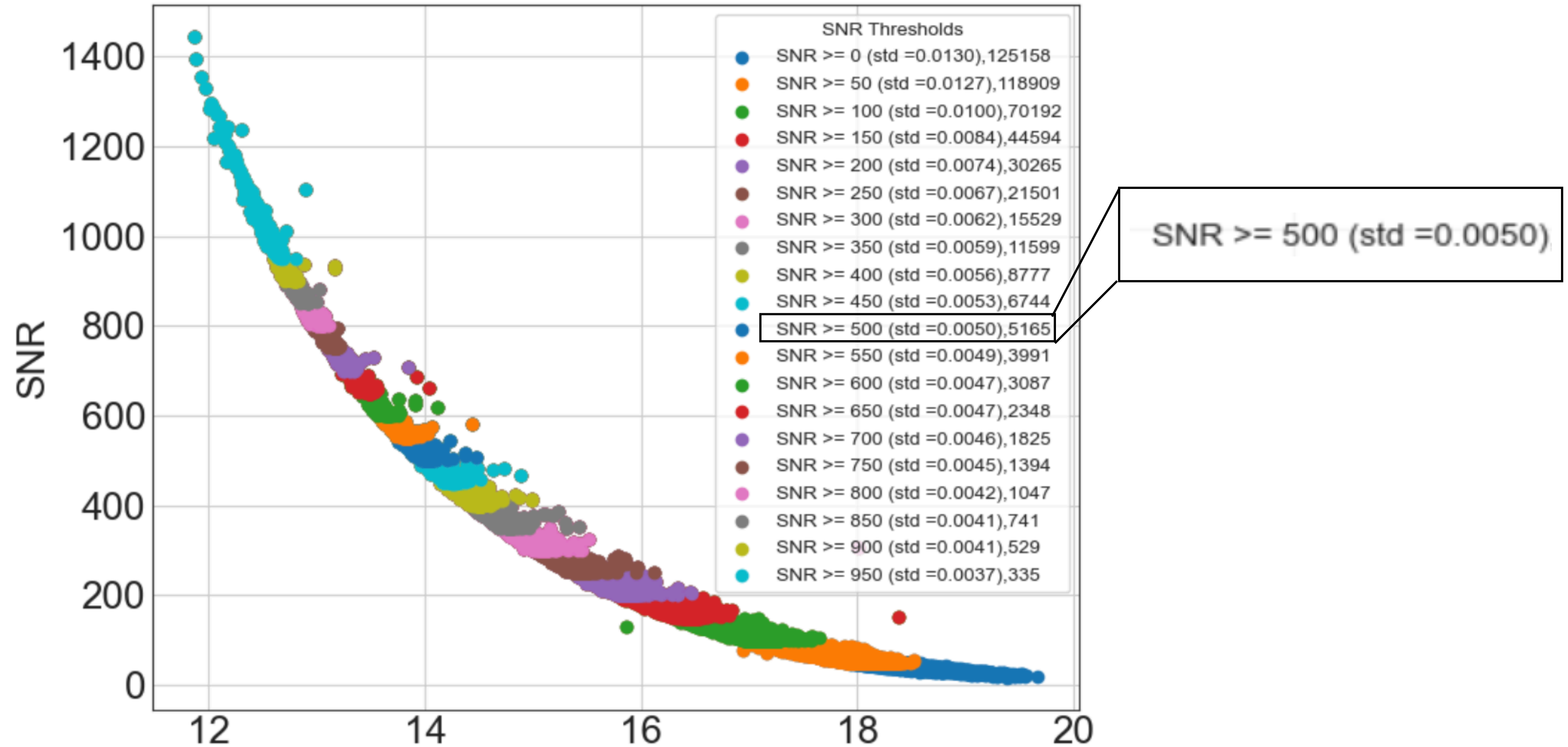


### Dichroic



### space





**The Gaia XP Synthetic photometry Method achieved a precision of 5mmag for (g - i) color of stars with SNR > 500, which is better than the precision obtained through photometric calibration for individual bands.**

# Calibration precision

Colors	ZP precision (SNR)
u-g	0.032 (300)
v-r	0.011 (300)
g-i	0.005 (500)
r-z	0.008 (550)

Bands	ZP precision (SNR)
u	0.031 (300)
v	0.011 (300)
g	0.005 (500)
r	0.005 (500)
i	0.005 (400)
z	0.006 (500)

- ◆ **The variation of zero-point correction with respect to each term across different time scales and spatial scales;**
- ◆ **Internal precision from repeat observation images;**
- ◆ **The impact of photometry with different methods on photometric calibration;**
- ◆ **The precision differences obtained by different calibration methods;**
- ◆ **Integrating photometric calibration into the processing of atmospheric parameter determination.**

- ◆ We use the synthetic photometry method with Gaia XP spectra to perform photometric calibration in six bands and color calibration in four bands for Mephisto targets.
- ◆ Except for the u-band, the photometric calibration precision can reach 10 mmag or even 5 mmag. The precision for the u-band is around 0.03 mag.
- ◆ The calibration precision for the four colors is comparable to or better than that obtained after single-band photometric calibration.

Bands / Colors	std of ZP (SNR)
u	0.031 (300)
v	0.011 (300)
g	0.005 (500)
r	0.005 (500)
i	0.005 (400)
z	0.006 (500)
u-g	0.032 (300)
v-r	0.011 (300)
g-i	0.005 (500)
r-z	0.008 (550)