Optimizing Large Scale Imaging Surveys for Relative Photometric Calibration, the Euclid Dark Energy Mission as an Example

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ABSTRACT

In this paper we show that, with due care given to the observing strategy, it will be possible to accurately constrain the relative photometric calibration of instruments used in large imaging surveys with their science data alone. We create end-to-end simulations of an imaging survey, which produces simulated datasets from mock observations of a synthetic sky according to a defined survey strategy. These catalog based simulations include realistic measurement uncertainties and a complex, position dependent instrument response. We then use a self-calibration technique to recover the relative instrument response by fitting an model that best explains the survey dataset, based on the multiple observations of (non-varying) sources at different focal plane positions. By considering four simple survey strategies we find that, with a correct redundancy built into the survey strategy, it is possible to accurately constrain the relative photometric response of an imaging instrument, and therefore the relative calibration of the resulting dataset. The majority of the remaining post self-calibration errors are due to the limitations in the basis used to model the relative instrument response. We find that returning the same sources to very different focal plane positions is the key property of a survey strategy that is required for an accurate calibration. From the results of this work, we are able to highlight an important point for those considering the design of large scale imaging surveys: depart from a regular tiling of the sky and return the same sources to very different focal plane positions.

Subject headings: Relative Photometric Calibration: Imaging Survey: Euclid

1. Introduction

Astronomers tend to think in terms of taking science data and calibration data separately. The former is used for science and the latter is used to constrain instrument parameters like the flat-field, the dark currents and so-on. But typically far more photons are collected during science exposures; are these not incredibly constraining on the calibration themselves? Indeed, in the retrospective photometric calibration of the Sloan Digital Sky Survey data (SDSS) (Padmanabhan et al. 2008) much more calibration information was obtained from the science data than the calibration data. But, of course, the SDSS imaging strategy had to be adjusted to make this calibration work: good redundancy is required in the data stream, and a redundancy of a very specific kind.

In this paper, we argue that the next generation of large surveys should have their observation strategies optimized from the very start with calibration in mind.

The question then just becomes: what makes a survey strategy good for the retrospective self-calibration of the dataset? In this paper, we focus on the relative photometric calibration of a typical imaging instrument only. For instrument parameters, we consider an instrument similar to the near-infrared photometric channel proposed for the European Space Agency's Euclid Dark Energy Mission.

and not just as an afterthought (as with SDSS), it will be possible to constrain calibration parameters to a high degree of accuracy.

turn to the planning of large imaging surveys, and not the retrospective

We feel, an

Why survey mission is unique etc

In this paper we summarize the end-to-end simulation used

In this paper we will show that this distinction between science and calibration data no longer applies in the large survey mission, both ground and space based, currently being planned and developed. We show that, as long as the survey strategy is designed appropriately, the calibration information within the science data can be used to accurately constrain the relative photometric response of an imaging instrument. This retrospective, cross-calibration of the dataset is a very powerful calibration method; future large scale imaging surveys should be optimized with this in mind.

We concentrate on catalog level simulations of different survey strategies and assess how well the resultant dataset can be used to constrain the relative response of the imaging instrument it came from. Although we do not model the imaging instrument on a pixel scale, we do include realistic measurement uncertainties within the simulations.

2. Discussion

In this paper, we have considered the optimization of survey strategies for calibrating the relative photometric response of an instrument, but we feel there are many more calibration parameters that can be constrained for this method. For example, the optical distortion of an instrument could also be constrained with such a method, although we concede that the properties of a survey strategy that makes them good for one calibration, may not be the same as that for another; ultimately a trade-off would need to be performed.

3. Acknowledgments

We are grateful to

REFERENCES

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Table 1. Sample table taken from ?

POS	chip	ID	X	Y	RA	DEC	IAU± δ IAU	IAP1± δ IAP1	IAP2 ± δ IAP2	star	E	Comment
0	2	1	1370.99	57.35	6.651120	17.131149	21.344±0.006	2 4.385±0.016	23.528±0.013	0.0	9	-
0	2	2	1476.62	8.03	6.651480	17.129572	21.641±0.005	2 3.141±0.007	22.007±0.004	0.0	9	-
0	2	3	1079.62	28.92	6.652430	17.135000	23.953±0.030	2 4.890±0.023	24.240±0.023	0.0	-	-
0	2	4	114.58	21.22	6.655560	17.148020	23.801±0.025	2 5.039±0.026	24.112±0.021	0.0	-	-
0	2	5	46.78	19.46	6.655800	17.148932	23.012±0.012	2 3.924±0.012	23.282±0.011	0.0	-	-
0	2	6	1441.84	16.16	6.651480	17.130072	24.393±0.045	2 6.099±0.062	25.119±0.049	0.0	-	-
0	2	7	205.43	3.96	6.655520	17.146742	24.424±0.032	2 5.028±0.025	24.597±0.027	0.0	-	-
0	2	8	1321.63	9.76	6.651950	17.131672	22.189±0.011	2 4.743±0.021	23.298±0.011	0.0	4	edge

Note. — Table 1 is published in its entirety in the electronic edition of the *Astrophysical Journal*. A portion is shown here for guidance regarding its form and content.

[a]Sample footnote for table 1 that was generated with the deluxetable environment

[b]Another sample footnote for table 1

Table 2. Literature Data for Program Stars

Star	V	b−y	m_1	c_1	ref	T_{eff}	log g	v_{turb}	[Fe/H]	ref
HD 97	9.7	0.51	0.15	0.35	2	···	···	···	−1.50	2
						5015	···	···	−1.50	10
HD 2665	7.7	0.54	0.09	0.34	2	···	···	···	−2.30	2
						5000	2.50	2.4	−1.99	5
						5120	3.00	2.0	−1.69	7
						4980	···	···	−2.05	10
HD 4306	9.0	0.52	0.05	0.35	20, 2	···	···	···	−2.70	2
						5000	1.75	2.0	−2.70	13
						5000	1.50	1.8	−2.65	14
						4950	2.10	2.0	−2.92	8
						5000	2.25	2.0	−2.83	18
						···	···	···	−2.80	21
						4930	···	···	−2.45	10
HD 5426	9.6	0.50	0.08	0.34	2	···	···	···	−2.30	2
HD 6755	7.7	0.49	0.12	0.28	20, 2	···	···	···	−1.70	2
						5200	2.50	2.4	−1.56	5
						5260	3.00	2.7	−1.67	7
						···	···	···	−1.58	21
						5200	···	···	−1.80	10
						4600	···	···	−2.75	10
HD 94028	8.2	0.34	0.08	0.25	20	5795	4.00	···	−1.70	22

Table 2—Continued

Star	V	b−y	m_1	c_1	ref	T_{eff}	log g	v_{turb}	[Fe/H]	ref
						5860	⋯	⋯	−1.70	4
						5910	3.80	⋯	−1.76	15
						5800	⋯	⋯	−1.67	17
						5902	⋯	⋯	−1.50	11
						5900	⋯	⋯	−1.57	3
						⋯	⋯	⋯	−1.32	21
HD 97916	9.2	0.29	0.10	0.41	20	6125	4.00	⋯	−1.10	22
						6160	⋯	⋯	−1.39	3
						6240	3.70	⋯	−1.28	15
						5950	⋯	⋯	−1.50	17
						6204	⋯	⋯	−1.36	11
This is a cut-in head										
+26°2606	9.7	0.34	0.05	0.28	20,11	5980	⋯	⋯	< -2.20	19
						5950	⋯	⋯	−2.89	24
+26°3578	9.4	0.31	0.05	0.37	20,11	5830	⋯	⋯	−2.60	4
						5800	⋯	⋯	−2.62	17
						6177	⋯	⋯	−2.51	11
						6000	3.25	⋯	−2.20	22
						6140	3.50	⋯	−2.57	15

Table 2—Continued

Star	V	b−y	m_1	c_1	ref	T_{eff}	log g	v_{turb}	[Fe/H]	ref
+30°2611	9.2	0.82	0.33	0.55	2	···	···	···	−1.70	2
						4400	1.80	···	−1.70	12
						4400	0.90	1.7	−1.20	14
						4260	···	···	−1.55	10
+37°1458	8.9	0.44	0.07	0.22	20,11	5296	···	···	−2.39	11
						5420	···	···	−2.43	3
+58°1218	10.0	0.51	0.03	0.36	2	···	···	···	−2.80	2
						5000	1.10	2.2	−2.71	14
						5000	2.20	1.8	−2.46	5
						4980	···	···	−2.55	10
+72°0094	10.2	0.31	0.09	0.26	12	6160	···	···	−1.80	19
I'm a side head:										
G5–36	10.8	0.40	0.07	0.28	20	···	···	···	−1.19	21
G18–54	10.7	0.37	0.08	0.28	20	···	···	···	−1.34	21
G20–08	9.9	0.36	0.05	0.25	20,11	5849	···	···	−2.59	11
						···	···	···	−2.03	21
G20–15	10.6	0.45	0.03	0.27	20,11	5657	···	···	−2.00	11
						6020	···	···	−1.56	3
						···	···	···	−1.58	21
G21–22	10.7	0.38	0.07	0.27	20,11	···	···	···	−1.23	21
G24–03	10.5	0.36	0.06	0.27	20,11	5866	···	···	−1.78	11

Table 2—Continued

Star	V	b−y	m_1	c_1	ref	T_{eff}	log g	v_{turb}	[Fe/H]	ref
						···	···	···	−1.70	21
G30–52	8.6	0.50	0.25	0.27	11	4757	···	···	−2.12	11
						4880	···	···	−2.14	3
G33–09	10.6	0.41	0.10	0.28	20	5575	···	···	−1.48	11
G66–22	10.5	0.46	0.16	0.28	11	5060	···	···	−1.77	3
						···	···	···	−1.04	21
G90–03	10.4	0.37	0.04	0.29	20	···	···	···	−2.01	21
LP 608–62[a]	10.5	0.30	0.07	0.35	11	6250	···	···	−2.70	4

[a]Star LP 608–62 is also known as BD+1°2341p. We will make this footnote extra long so that it extends over two lines.

References. — (1) Barbuy, Spite, & Spite 1985; (2) Bond 1980; (3) Carbon et al. 1987; (4) Hobbs & Duncan 1987; (5) Gilroy et al. 1988: (6) Gratton & Ortolani 1986; (7) Gratton & Sneden 1987; (8) Gratton & Sneden (1988); (9) Gratton & Sneden 1991; (10) Kraft et al. 1982; (11) LCL, or Laird, 1990; (12) Leep & Wallerstein 1981; (13) Luck & Bond 1981; (14) Luck & Bond 1985; (15) Magain 1987; (16) Magain 1989; (17) Peterson 1981; (18) Peterson, Kurucz, & Carney 1990; (19) RMB; (20) Schuster & Nissen 1988; (21) Schuster & Nissen 1989b; (22)

Spite et al. 1984; (23) Spite & Spite 1986; (24) Hobbs & Thorburn 1991; (25) Hobbs et al. 1991; (26) Olsen 1983.