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Mount model of 1.2 m telescope at Kunming station

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Abstract

Mount model is important for a telescope, especially in autonomous application. The 1.2m telescope at Kunming station is an Alt-Az mount telescope, with coude optics path and a bind night track sub-system. Using a sCMOS mounted in the end of coude optics path, in which the field of view is rotating, we achieved the pointing accuracy about 1 arc second. The mount model consists of fundamental terms (like encoder offset, collimation, tube flexure, etc), and spheric harmonic terms determined by residual analysis.

Introduction

To track invisible objects day and night, automated observe objects, acquire fai nt objects rapidly, good pointing accura cy of a telescope is required. It is a parti cularly stringent requirement in LLR. M ount Stromlo Observatory reported tha t a Mount Model which yields 1" absolu te accuracy for many months is constru cted. The model depends on the structu res, mechanism and optics. Besides the fundamental terms are related to physic al reasons, speric harmonics terms and polynomial terms are usually concerned.

Structure

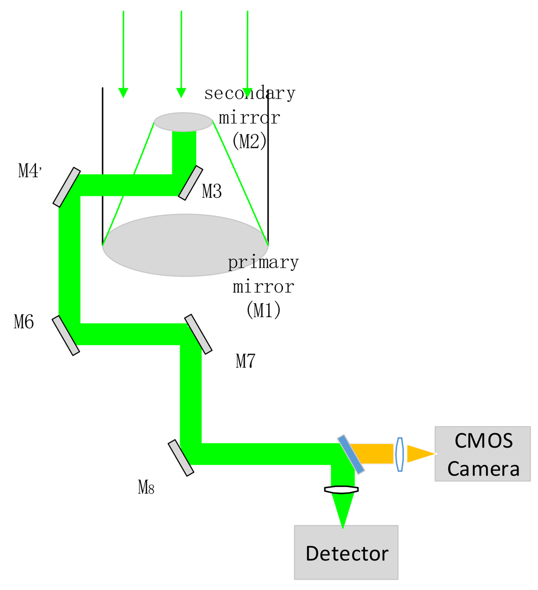
Mechanism

Tube: solid

Azimuth: droved by two motor in friction way.

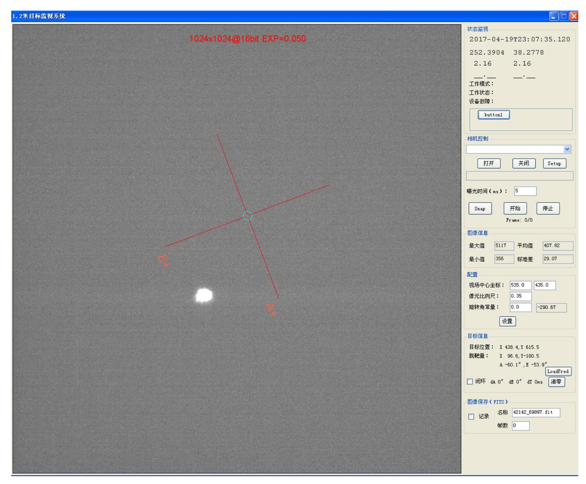
Elevation: drove by on motor directly.

Optics



The camera is a Hamamatsu sCMOS, C13440-20CU, 2048×2048. The pixel resolution is about 0.175". It worked in binning 2 mode, so the pixel resolution is about 0.35".

Rotation of FOV



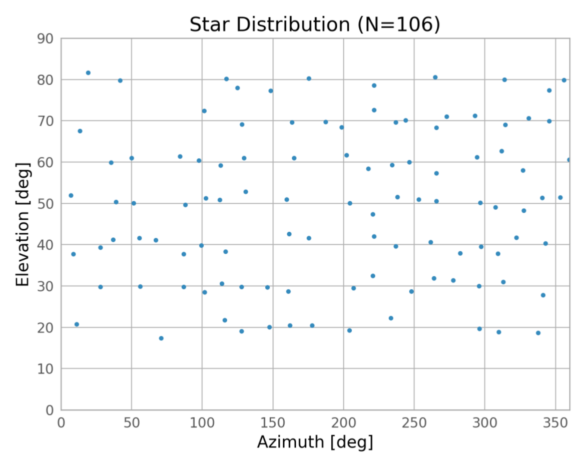
The fig is the GUI of image capture software. The red cross shows the rotation of field-of-view, with A+, E+ indicators.

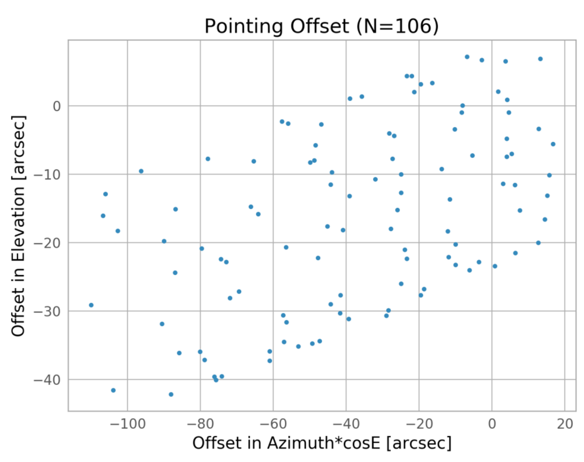
$$dA = [dX * \cos(-A+E) + dY * \sin(-A+E)] / \cos E$$

$$dE = -[-dX * \sin(-A+E) + dY * \cos(-A+E)]$$

Mount Model

Observation and Pre-Processing





$$\delta A = A_{obs} - A_{theory} \qquad A_{obs} = A_{encoder} + A_{offset}$$

$$\delta E = E_{obs} - E_{theory\ with\ refraction} \qquad E_{obs} = E_{encoder} + E_{offset}$$

Theory positions with refracion are calculated using a python package named skyfield. The core code is as followings:

```
site_ynao = api.Topos(latitude='25.0299 N',
                      longitude='102.7974 E',
                      elevation_m=1991.83)
earth = load('de430_2000-2100.bsp')['earth']
star = api.Star.from_dataframe(df.loc[star_id])
site= earth + site_topos
astrometric = site.at(t).observe(star)
alt, az, d = astrometric.apparent().altaz(T, P)
```

The centroid of stars are determined by using SExtractor. The star is usually not exactly in the center of field-of-view, an offset exists. The offset in pixels is then converted to offset in Azimuth and Elevation separately, considering the rotation of field-of-view and the pixel resolution.

Model

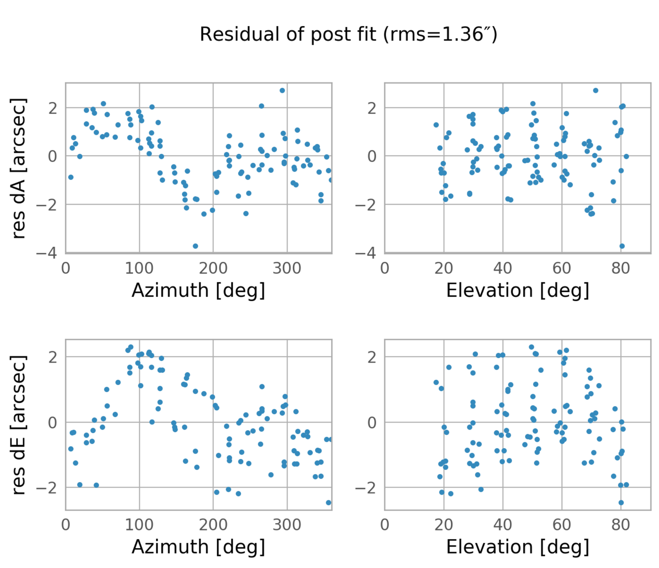
$$\delta A_i = (A_{obs} - A_{theory})_i = \sum_j c_j F_j(A_i, E_i)$$

$$\delta E_i = (E_{obs} - E_{theory\ with\ refraction})_i = \sum_j c_j G_j(A_i, E_i)$$

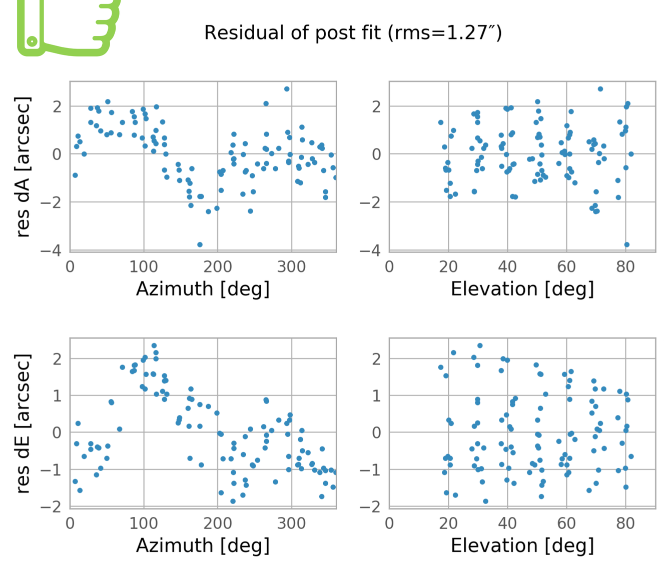
Basic model (Fundamental terms)

20190603（rms：1.36"，condition number：3.25e+03）

No	Term	Value	Azimuth Function	Elevation Function
1	IA	115.25	1.0	-
2	IE	-32.40	-	1.0
3	CA	92.14	-secE	-
4	AN	-9.66	-sinAtanE	-cosA
5	AW	11.26	-cosAtaE	sinA
6	NPAE	21.89	-tanE	-
7	TF_ALTAZ	-26.95	-	cosE
8	CRX	0.11	cos(A-E)secE	-sin(A-E)
9	CRY	-1.75	-sin(A-E)secE	-cos(A-E)

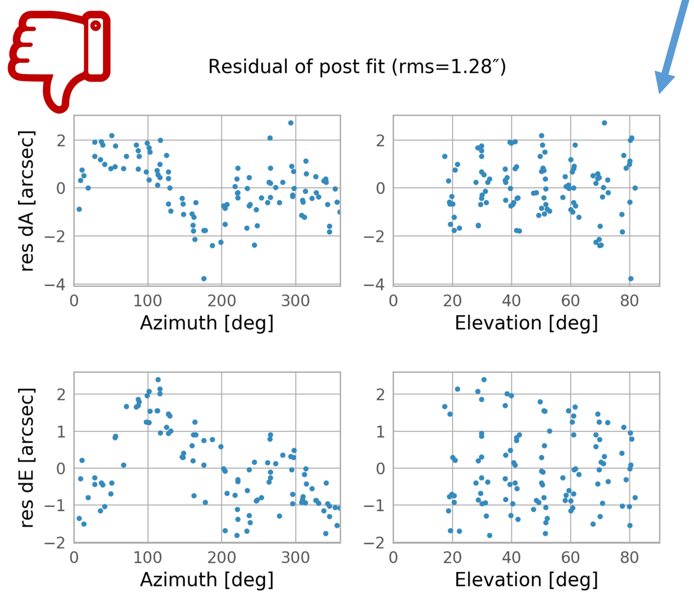


Basic model (cond_num: 3.25e+03)



+(HESE4、HECE4)

rms 1.36" → 1.28", cond_num 3.25e+3 → 5.69e+3



+(HESE2、HECE2)

rms 1.36" → 1.27", cond_num 3.25e+3 → 1.64e+5

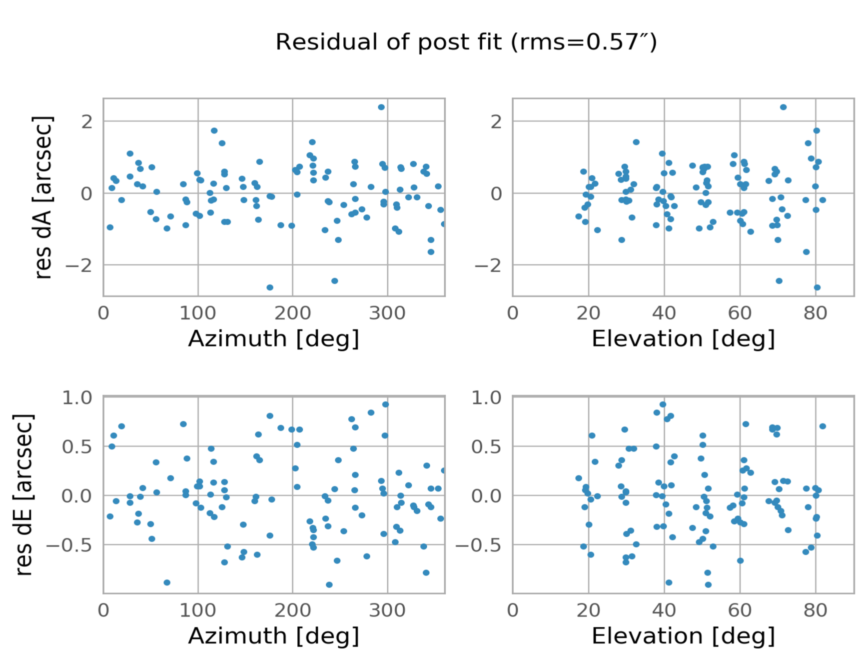
Condition number increases remarkably.

No	Term	Basic Model rms：1.36"，cond_num：3.25e+03	+(HESE2、HECE2) rms：1.27"，cond_num：1.64e+05	+(HESE4、HECE4) rms：1.28"，cond_num：5.69e+03
1	IA	115.25	115.26	115.26
2	IE	-32.40	-21.98	-30.53
3	CA	92.14	92.17	92.17
4	AN	-9.66	-9.66	-9.66
5	AW	11.26	11.21	11.21
6	NPAE	21.89	21.87	21.87
7	**TF_ALTAZ**	**-26.95**	**-9.08**	**-24.28**
8	CRX	0.11	0.09	0.09
9	CRY	-1.75	-1.80	-1.79
10		-	(HESE2) 1.91	(HESE4) 1.09
11		-	(HECE2) 7.41	(HECE4) 0.31

Result

20190603（rms：0.57"，cond_num：6.18e+03）

No	Term	Value	Azimuth Function	Elevation Function
1	IA	115.56	1.0	-
2	IE	-30.97	-	1.0
3	CA	92.60	-secE	-
4	AN	-7.93	-sinAtanE	-cosA
5	AW	11.03	-cosAtaE	sinA
6	NPAE	21.53	-tanE	-
7	TF_ALTAZ	-25.09	-	cosE
8	CRX	2.00	cos(A-E)secE	-sin(A-E)
9	CRY	-1.91	-sin(A-E)secE	-cos(A-E)
10	HESA	0.43	-	sinA
11	HECA	0.74	-	cosA
12	HESA2	0.45	-	sin2A
13	HECA2	0.58	-	cos2A
14	HESE4	0.94	-	sin4E
15	HECE4	0.44	-	cos4E
16	HASA	-1.03	sinA	-
17	HASA	-2.78	cosA	-
18	HASA2	-0.27	sin2A	-
19	HACA2	0.86	cos2A	-



The final mount model consists of 19 terms, 7 terms are fundamental terms, 2 terms are related to coude path, and 10 terms are spheric harmonics, determined by residual analysis. The residual are most likely white noise.

The rms is better than 1".

And the model is suitable, checked many times in different days. While the stability is the next point.

contact me

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