Analysis of Guiding an Equatorial Platform with PHD2 Software

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Introduction

The Stark Labs PHD2 is a popular free software program that does an excellent job guiding equatorial mount telescopes for prolonged exposure astrophotography. Equatorial platforms provide a way to also use large Dobsonian telescopes for astrophotography. Unfortunately, the PHD2 program can only guide over a limited portion of the night sky. The purpose of this paper is to document a spreadsheet used to analyze PHD2 limitations and offer corrections that improve guiding over the entire sky.

Operation

Swing of a typical equatorial platform is 20 degrees which gives 80 minutes of operation before it needs to be reset to its starting position. Since the initial starting position is 10 degrees from horizontal the time or location must be offset in the telescope control to be able to automatically seek out objects of interest.

Initial platform tilt when looking east has the telescope pointing lower than its level position placing stars higher than normal in the sky. The tilt effect can be neutralized by adding 40 minutes to the telescope control time setting or moving the longitude setting 10 degrees to the east. Once the desired object is located using the telescope automation, the control tracking is turned off and platform tracking is turn on.

Analysis

The spreadsheet includes typical observation site and celestial object input parameters. Initial object local hour, altitude, and azimuth angles are calculated using well understood formulas. The equatorial platform effects on observed object altitude and azimuth during PHD2 calibration are simulated by selectable angle east/west shifts in longitude for platform right ascension moves and north/south shifts in latitude for platform declination moves.

Initial and final object positions are used to compute changes in observed altitude and azimuth due to equatorial platform calibration. Altitude and azimuth calibration factors are computed using the ratio of desired to actual guide star movements. Total tracking time is used as an offset to the local hour angle to calculate its effect on calibration and associated correction factors. Provision is also made to display the drift that would occur with the passage of time due to tracking rate error and using offset angles as errors in polar alignment.

Results

Figures 1-4 shows the effect of the equatorial platform geometry on desired and predicted PHD2 altitude and azimuth calibration steps for telescope pointing positions of 0, 90, 180, 270 degrees. Figures 5 and 7 show good agreement between calculated and measured calibration steps for celestial objects in various parts of the sky. Figures 6 and 8 shows detailed calculations for the two example celestial objects.

Discussion

In general guiding of an equatorial platform using PHD2 software gets difficult or even impossible as pointing positions get further from the southern half of the sky. A simple work around is to limit guiding to objects that transient the meridian in the south and select imaging sessions near that meridian transient time. An inspection of the various analysis runs provides insight into limitations of equatorial platform PHD2 guiding and suggests beneficial strategies in its use or even eventual improvement to its control structure.

Figure 1 for the north pointing case shows the direction of the predicted right ascension calibration motion (blue) is opposite the desired motion direction (green) and quite small in amplitude. The predicted declination calibration motion (red) aligns nicely in both direction and amplitude with the desired motion (orange). Since the telescope is pointing close to the celestial pole, star drift (purple) is almost negligible and control could be limited to just the declination axis.

Figure 2 for the east pointing case shows a large angle between predicted and desired right ascension motions but at least the directions are the same polarity. The predicted declination calibration motion is nicely aligned in direction with the desired motion but somewhat attenuated in amplitude. This reasonably aligned declination calibration is like that of other pointing directions. The drift magnitude becomes more significant as the pointing position moves further from the celestial pole.

Figure 3 for the south pointing case shows good alignment of both the right ascension and declination motions. The predicted right ascension motion amplitude is amplified and drift due to polar alignment error is significant. Figure 4 for the west pointing case shows a pattern like that of the east pointing case. A beneficial strategy for east and west pointing directions is to turn down aggressiveness of right ascension control so as not to overwhelm declination control.

Figure 5 for the NGC5965 spiral galaxy case shows good agreement between predicted and measured calibration motions. The alignment of predicted and desired calibration motions is like that of the west pointing case. Figure 7 for the NGC1569 irregular galaxy case also shows good agreement between predicted and measured calibration motions. The predicted right ascension motion shows almost no contribution to desired motion of that axis.

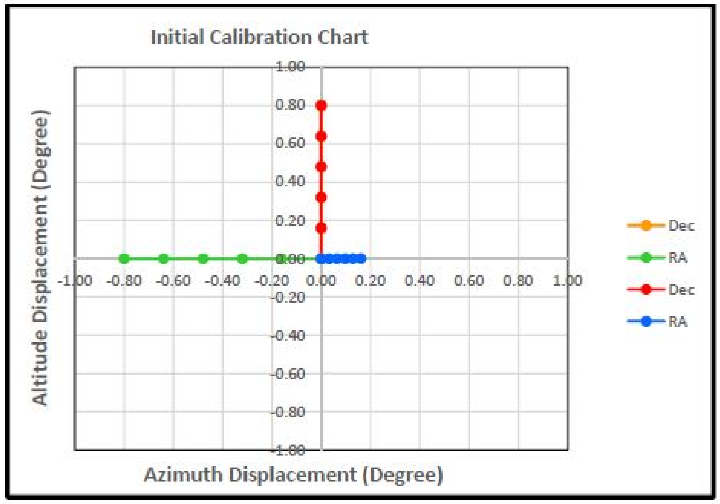
Calculation details in Figure 6 and 8 for the two galaxies show large deviations between predicted and desired altitude and azimuth motions during right ascension calibration. On the other hand, the predicted and desired motions are reasonably consistent for declination calibration. Guiding in the northern part of the sky will be difficult or impossible due to right ascension motion commands distortion. Future improvements in PHD2 software for equatorial platform guiding could initially focus on the behavior of right ascension control.

Site Parameters	Code	Value	Units
Location Time Offset	Tof	-6.00	Hour
Location Latitude	Lat	40.583	Degree
Location Longitude	Lon	111.800	Degree
Location Elevation	Ele	1550	Meter
Observation Year	Year	2017	Year
Observation Month	Mon	9	Month
Observation Day	Day	10	Day
Observation Hour	Hour	0	Hour
Observation Minute	Min	0	Minute
Observation Minute	Sec	0	Second
Input Parameters	**Code**	**Value**	**Units**
Object Ascension	Oasci	9.844	Hour
Object Declination	Odecl	80.000	Degree
East West Angle	Aew	0.800	Degree
North South Angle	Ans	0.800	Degree
Tracking Time Error	Tte	0.000	Hour
Tracking Time Total	Ttt	1.000	Hour

Output Parameters	Code	Value	Units
	π	3.142	
Julian Date	JD	2458007	Day
Universal Date	UT	6462	Day
Greenwich Time	GMST	5.298	Hour
Object Altitude	Oalt	30.583	Degree
Object Azimuth	Oazm	0.000	Degree
Axis Orthogonality	Orth	-89.695	Degree

Drift Alignmment

Location	Offset	Pointed	Drift
South	West (-)	West	Down
South	East (+)	East	Up
East	South (-)	Above	Down
East	North (+)	Below	Up
West	South (-)	Above	Up
West	North (+)	Below	Down



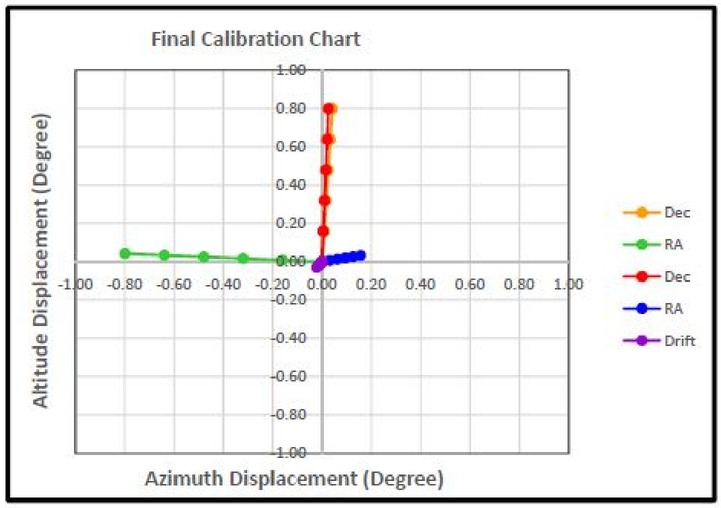


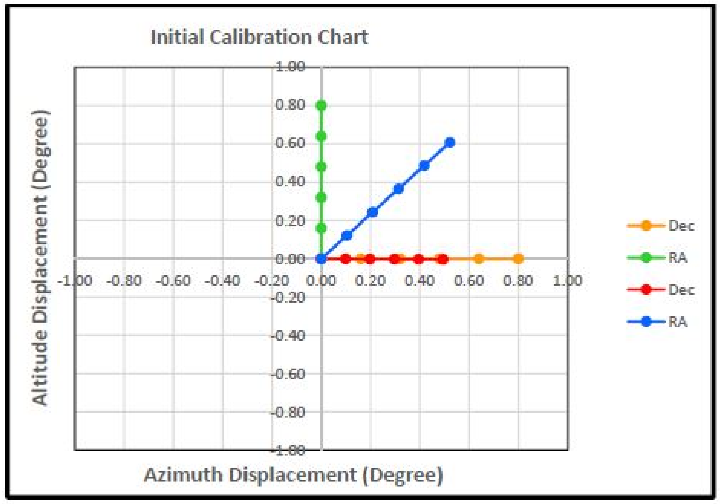
Figure 1 PHD2 Calibration at Azimuth Pointing Position of 0 Degrees

Site Parameters	Code	Value	Units
Location Time Offset	Tof	-6.00	Hour
Location Latitude	Lat	40.583	Degree
Location Longitude	Lon	111.800	Degree
Location Elevation	Ele	1550	Meter
Observation Year	Year	2017	Year
Observation Month	Mon	9	Month
Observation Day	Day	10	Day
Observation Hour	Hour	0	Hour
Observation Minute	Min	0	Minute
Observation Minute	Sec	0	Second
Input Parameters	**Code**	**Value**	**Units**
Object Ascension	Oasci	2.168	Hour
Object Declination	Odecl	20.000	Degree
East West Angle	Aew	0.800	Degree
North South Angle	Ans	0.800	Degree
Tracking Time Error	Tte	0.000	Hour
Tracking Time Total	Ttt	1.000	Hour

Output Parameters	Code	Value	Units
	π	3.142	
Julian Date	JD	2458007	Day
Universal Date	UT	6462	Day
Greenwich Time	GMST	5.298	Hour
Object Altitude	Oalt	31.718	Degree
Object Azimuth	Oazm	90.000	Degree
Axis Orthogonality	Orth	49.722	Degree

Drift Alignmment

Location	Offset	Pointed	Drift
South	West (-)	West	Down
South	East (+)	East	Up
East	South (-)	Above	Down
East	North (+)	Below	Up
West	South (-)	Above	Up
West	North (+)	Below	Down



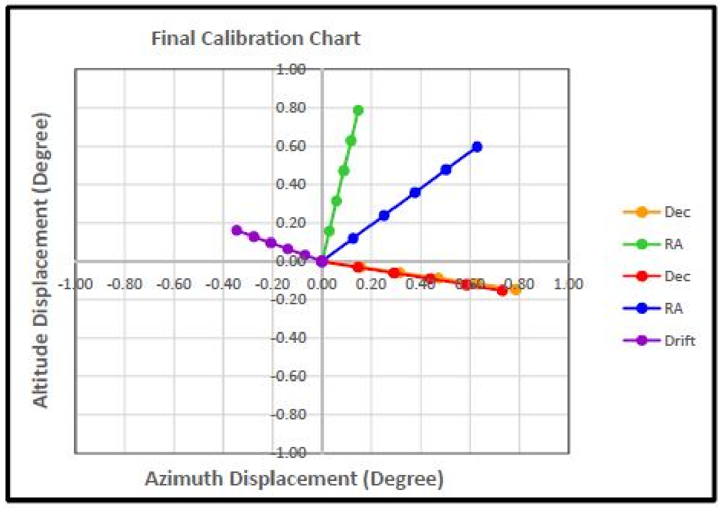


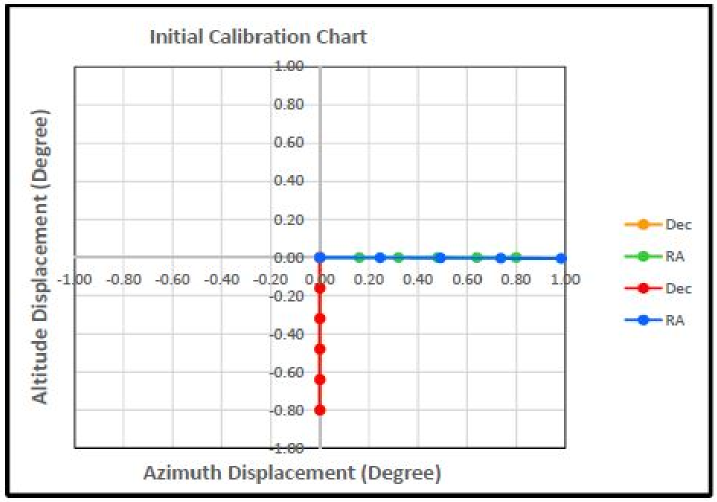
Figure 2 PHD2 Calibration at Azimuth Pointing Position of 90 Degrees

Site Parameters	Code	Value	Units
Location Time Offset	Tof	-6.00	Hour
Location Latitude	Lat	40.583	Degree
Location Longitude	Lon	111.800	Degree
Location Elevation	Ele	1550	Meter
Observation Year	Year	2017	Year
Observation Month	Mon	9	Month
Observation Day	Day	10	Day
Observation Hour	Hour	0	Hour
Observation Minute	Min	0	Minute
Observation Minute	Sec	0	Second
Input Parameters	**Code**	**Value**	**Units**
Object Ascension	Oasci	21.845	Hour
Object Declination	Odecl	0.000	Degree
East West Angle	Aew	0.800	Degree
North South Angle	Ans	0.800	Degree
Tracking Time Error	Tte	0.000	Hour
Tracking Time Total	Ttt	1.000	Hour

Output Parameters	Code	Value	Units
	π	3.142	
Julian Date	JD	2458007	Day
Universal Date	UT	6462	Day
Greenwich Time	GMST	5.298	Hour
Object Altitude	Oalt	49.417	Degree
Object Azimuth	Oazm	180.000	Degree
Axis Orthogonality	Orth	89.696	Degree

Drift Alignment

Location	Offset	Pointed	Drift
South	West (-)	West	Down
South	East (+)	East	Up
East	South (-)	Above	Down
East	North (+)	Below	Up
West	South (-)	Above	Up
West	North (+)	Below	Down



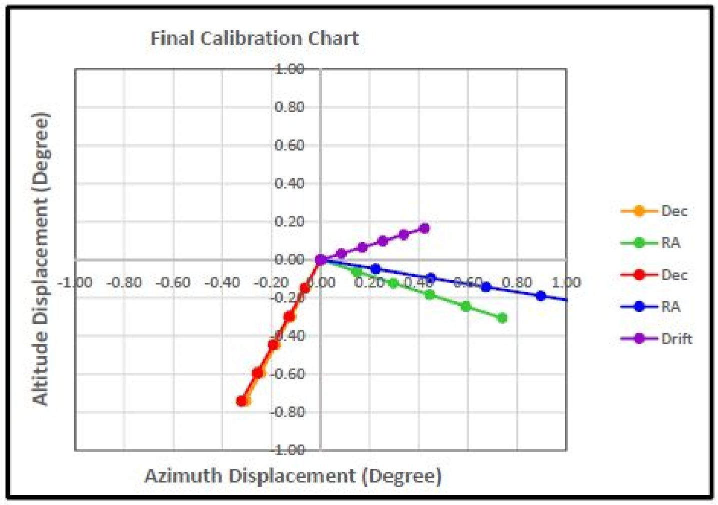
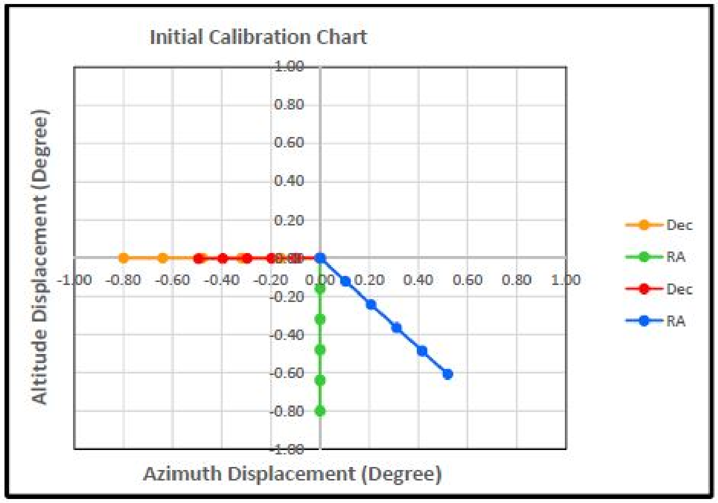


Figure 3 PHD2 Calibration at Azimuth Pointing Position of 180 Degrees

Site Parameters	Code	Value	Units
Location Time Offset	Tof	-6.00	Hour
Location Latitude	Lat	40.583	Degree
Location Longitude	Lon	111.800	Degree
Location Elevation	Ele	1550	Meter
Observation Year	Year	2017	Year
Observation Month	Mon	9	Month
Observation Day	Day	10	Day
Observation Hour	Hour	0	Hour
Observation Minute	Min	0	Minute
Observation Minute	Sec	0	Second
Input Parameters	**Code**	**Value**	**Units**
Object Ascension	Oasci	17.521	Hour
Object Declination	Odecl	20.000	Degree
East West Angle	Aew	0.800	Degree
North South Angle	Ans	0.800	Degree
Tracking Time Error	Tte	0.000	Hour
Tracking Time Total	Ttt	1.000	Hour



Output Parameters	Code	Value	Units
	π	3.142	
Julian Date	JD	2458007	Day
Universal Date	UT	6462	Day
Greenwich Time	GMST	5.298	Hour
Object Altitude	Oalt	31.718	Degree
Object Azimuth	Oazm	270.000	Degree
Axis Orthogonality	Orth	130.092	Degree

Drift Alignment

Location	Offset	Pointed	Drift
South	West (-)	West	Down
South	East (+)	East	Up
East	South (-)	Above	Down
East	North (+)	Below	Up
West	South (-)	Above	Up
West	North (+)	Below	Down

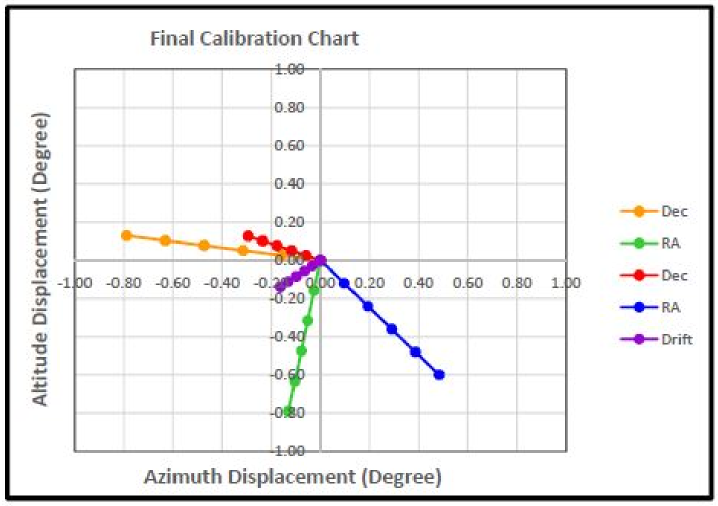


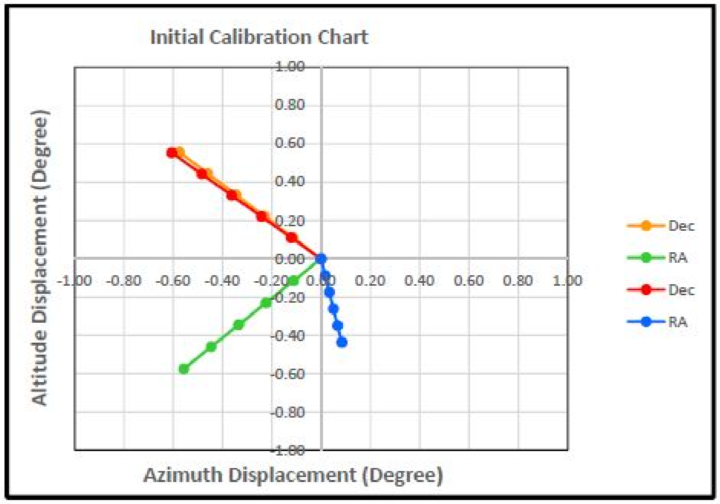
Figure 4 PHD2 Calibration Calculation at Azimuth Pointing Position of 270 Degrees

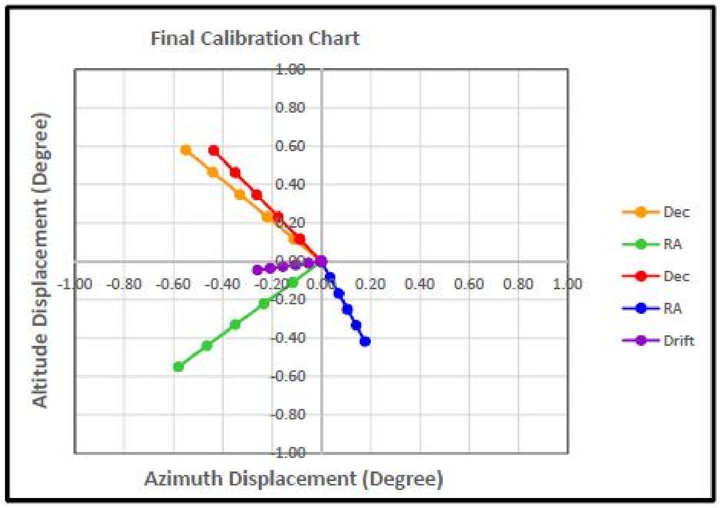
Site Parameters	Code	Value	Units
Location Time Offset	Tof	-6.00	Hour
Location Latitude	Lat	40.583	Degree
Location Longitude	Lon	111.800	Degree
Location Elevation	Ele	1550	Meter
Observation Year	Year	2017	Year
Observation Month	Mon	9	Month
Observation Day	Day	10	Day
Observation Hour	Hour	22	Hour
Observation Minute	Min	0	Minute
Observation Minute	Sec	0	Second
Input Parameters	**Code**	**Value**	**Units**
Object Ascension	Oasci	15.574	Hour
Object Declination	Odecl	56.629	Degree
East West Angle	Aew	0.800	Degree
North South Angle	Ans	0.800	Degree
Tracking Time Error	Tte	0.000	Hour
Tracking Time Total	Ttt	1.000	Hour

Output Parameters	Code	Value	Units
	π	3.142	
Julian Date	JD	2458008	Day
Universal Date	UT	6463	Day
Greenwich Time	GMST	3.358	Hour
Object Altitude	Oalt	46.062	Degree
Object Azimuth	Oazm	314.091	Degree
Axis Orthogonality	Orth	143.445	Degree

Drift Alignmnment

Location	Offset	Pointed	Drift
South	West (-)	West	Down
South	East (+)	East	Up
East	South (-)	Above	Down
East	North (+)	Below	Up
West	South (-)	Above	Up
West	North (+)	Below	Down





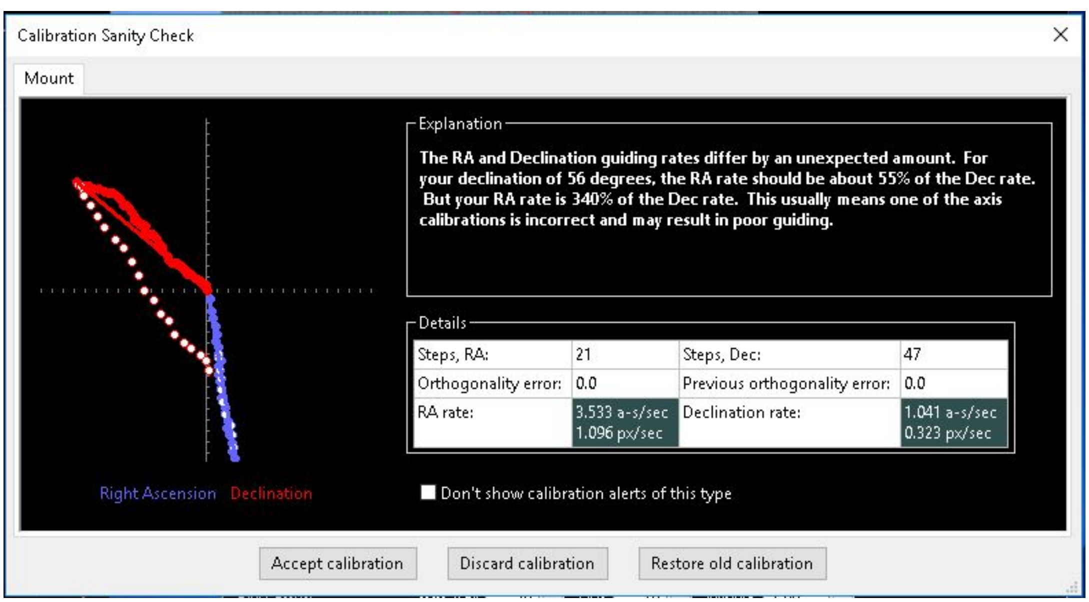


Figure 5 PHD2 Calibration Calculation and Measurement for NGC5965 Spiral Galaxy

Output Parameters	Code	Aew (RA)	Ans (Dec)	Aew (RA)	Ans (Dec)	Both Axis
Object Local Hour	Olhai	4.331	4.331	5.331	5.331	4.331
Object Altitude	Oalti	46.062	46.062	38.033	38.033	46.062
Object Azimuth	Oazmi	314.091	314.091	316.555	316.555	314.091
Platform Local Hour	Plhai	4.384	4.331	5.384	5.331	4.384
Platform Altitude	Palti	45.626	46.616	37.616	38.611	46.181
Platform Azimuth	Pazmi	314.176	313.486	316.733	316.119	313.581
Delta Altitude	Dalt	-0.436	0.554	-0.417	0.579	0.118
Delta Azimuth	Dazm	0.085	-0.605	0.177	-0.437	-0.510
Delta Vector Total	Dtot	0.444	0.820	0.453	0.725	0.524
Delta Vector Angle	Dvec	169.007	312.452	156.951	322.972	283.064
Altitude Fraction	Falt	0.982	0.675	0.920	0.798	0.226
Azimuth Fraction	Fazm	0.191	0.738	0.392	0.602	0.974
Declination Angle	Adec	145.084	1.639	159.604	-6.416	31.027
Ascension Angle	Aasc	55.084	-88.361	69.604	-96.416	-58.973
Declination Motion	Mdec	-0.364	0.820	-0.425	0.720	0.449
Ascension Motion	Masc	0.254	0.023	0.158	-0.081	0.270
Object Final Lha	Olhaf					5.331
Object Final Alt	Oaltf					38.033
Object Final Azm	Oazmf					316.555
Platform Final Lha	Plhaf					5.384
Platform Final Alt	Paltf					38.196
Platform Final Azm	Pazmf					316.304
Drift Altitude	Ealt					-0.045
Drift Azimuth	Eazm					-0.259
Drift Vector Total	Etot					0.263
Drift Vector Angle	Evec					260.170

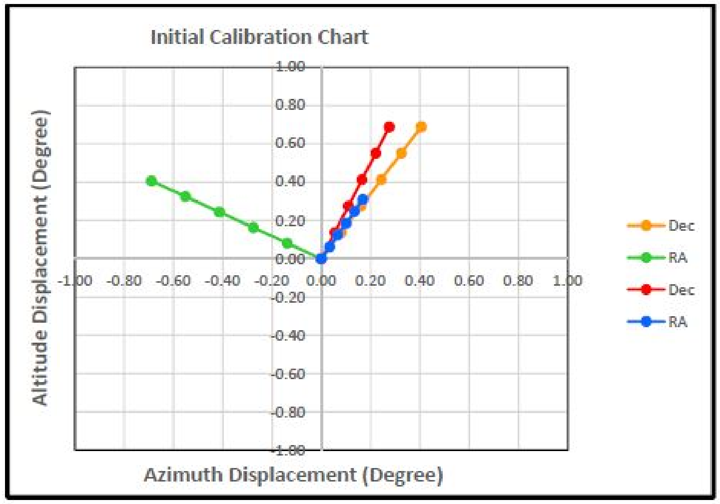
Figure 6 PHD2 Analyzer Spreadsheet Calculation Details for NGC5965 Spiral Galaxy

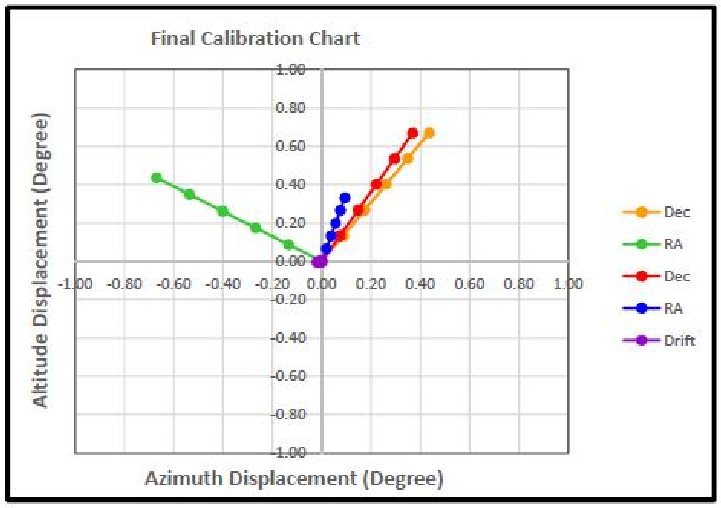
Site Parameters	Code	Value	Units
Location Time Offset	Tof	-6.00	Hour
Location Latitude	Lat	40.583	Degree
Location Longitude	Lon	111.800	Degree
Location Elevation	Ele	1550	Meter
Observation Year	Year	2017	Year
Observation Month	Mon	9	Month
Observation Day	Day	11	Day
Observation Hour	Hour	0	Hour
Observation Minute	Min	14	Minute
Observation Minute	Sec	0	Second
Input Parameters	**Code**	**Value**	**Units**
Object Ascension	Oasci	4.542	Hour
Object Declination	Odecl	64.883	Degree
East West Angle	Aew	0.800	Degree
North South Angle	Ans	0.800	Degree
Tracking Time Error	Tte	0.000	Hour
Tracking Time Total	Ttt	1.000	Hour

Output Parameters	Code	Value	Units
	π	3.142	
Julian Date	JD	2458008	Day
Universal Date	UT	6463	Day
Greenwich Time	GMST	5.598	Hour
Object Altitude	Oalt	33.747	Degree
Object Azimuth	Oazm	30.512	Degree
Axis Orthogonality	Orth	-6.801	Degree

Drift Alignmment

Location	Offset	Pointed	Drift
South	West (-)	West	Down
South	East (+)	East	Up
East	South (-)	Above	Down
East	North (+)	Below	Up
West	South (-)	Above	Up
West	North (+)	Below	Down





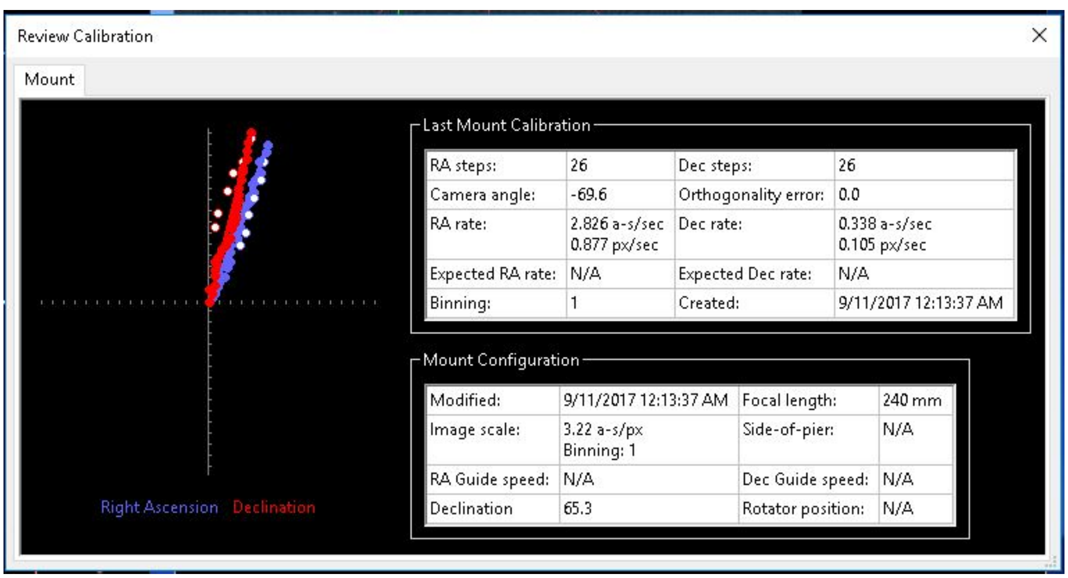


Figure 7 PHD2 Calibration Calculation and Measurement for NGC1569 Irregular Galaxy

Output Parameters	Code	Aew (RA)	Ans (Dec)	Aew (RA)	Ans (Dec)	Both Axis
Object Local Hour	Olhai	17.602	17.602	18.602	18.602	17.602
Object Altitude	Oalti	33.747	33.747	39.765	39.765	33.747
Object Azimuth	Oazmi	30.512	30.512	33.050	33.050	30.512
Platform Local Hour	Plhai	17.656	17.602	18.656	18.602	17.656
Platform Altitude	Palti	34.056	34.435	40.097	40.435	34.743
Platform Azimuth	Pazmi	30.681	30.788	33.144	33.419	30.962
Delta Altitude	Dalt	0.309	0.688	0.332	0.669	0.996
Delta Azimuth	Dazm	0.169	0.276	0.094	0.369	0.450
Delta Vector Total	Dtot	0.352	0.742	0.345	0.764	1.093
Delta Vector Angle	Dvec	28.655	21.854	15.880	28.888	24.291
Altitude Fraction	Falt	0.878	0.928	0.962	0.876	0.911
Azimuth Fraction	Fazm	0.480	0.372	0.274	0.483	0.411
Declination Angle	Adec	1.857	8.658	17.169	4.161	6.221
Ascension Angle	Aasc	-88.143	-81.342	-72.831	-85.839	-83.779
Declination Motion	Mdec	0.352	0.733	0.330	0.762	1.087
Ascension Motion	Masc	0.011	0.112	0.102	0.055	0.118
Object Final Lha	Olhaf					18.602
Object Final Alt	Oaltf					39.765
Object Final Azm	Oazmf					33.050
Platform Final Lha	Plhaf					18.656
Platform Final Alt	Paltf					40.766
Platform Final Azm	Pazmf					33.518
Drift Altitude	Ealt					-0.004
Drift Azimuth	Eazm					-0.019
Drift Vector Total	Etot					0.020
Drift Vector Angle	Evec					258.518

Figure 8 PHD2 Analyzer Spreadsheet Calculation Details for NGC1569 Irregular Galaxy