Spacecraft Motions

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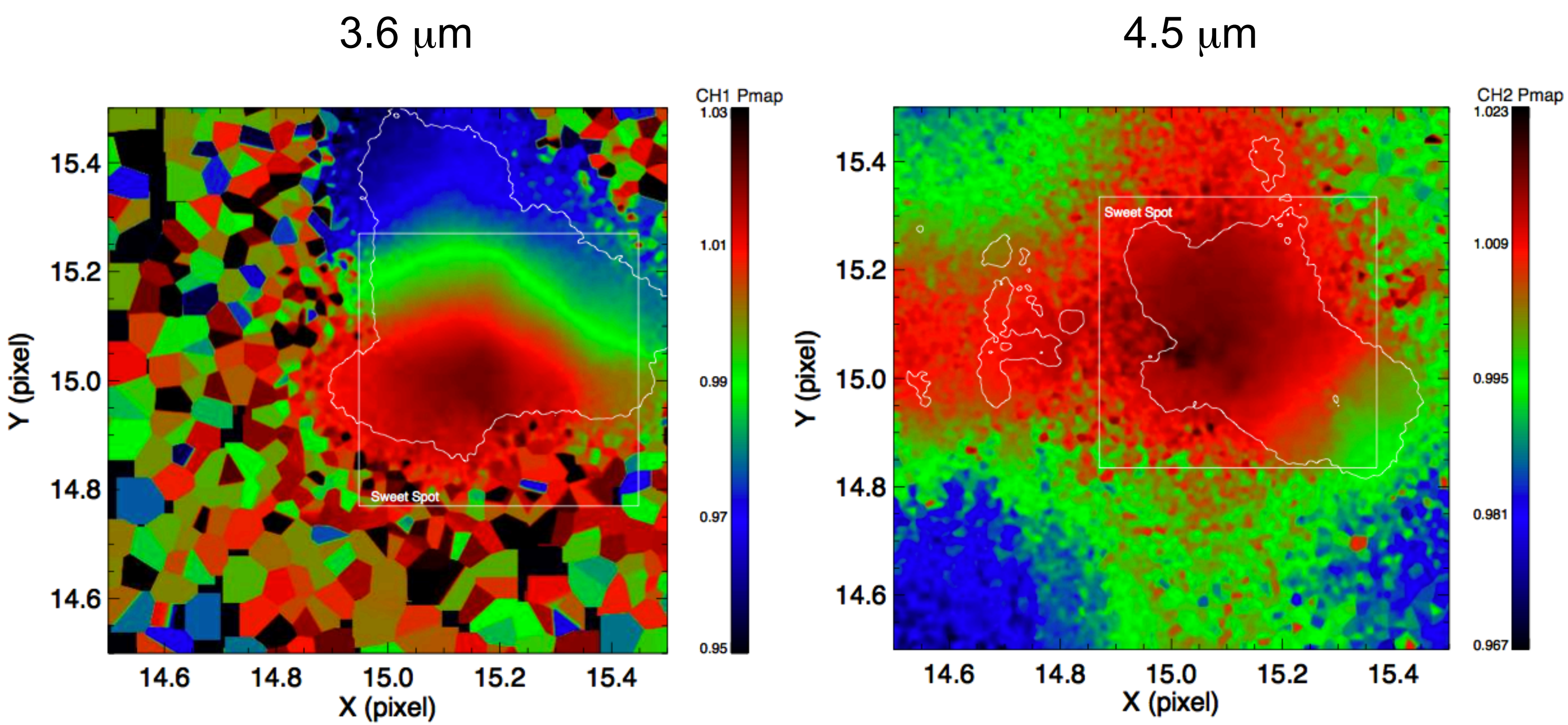
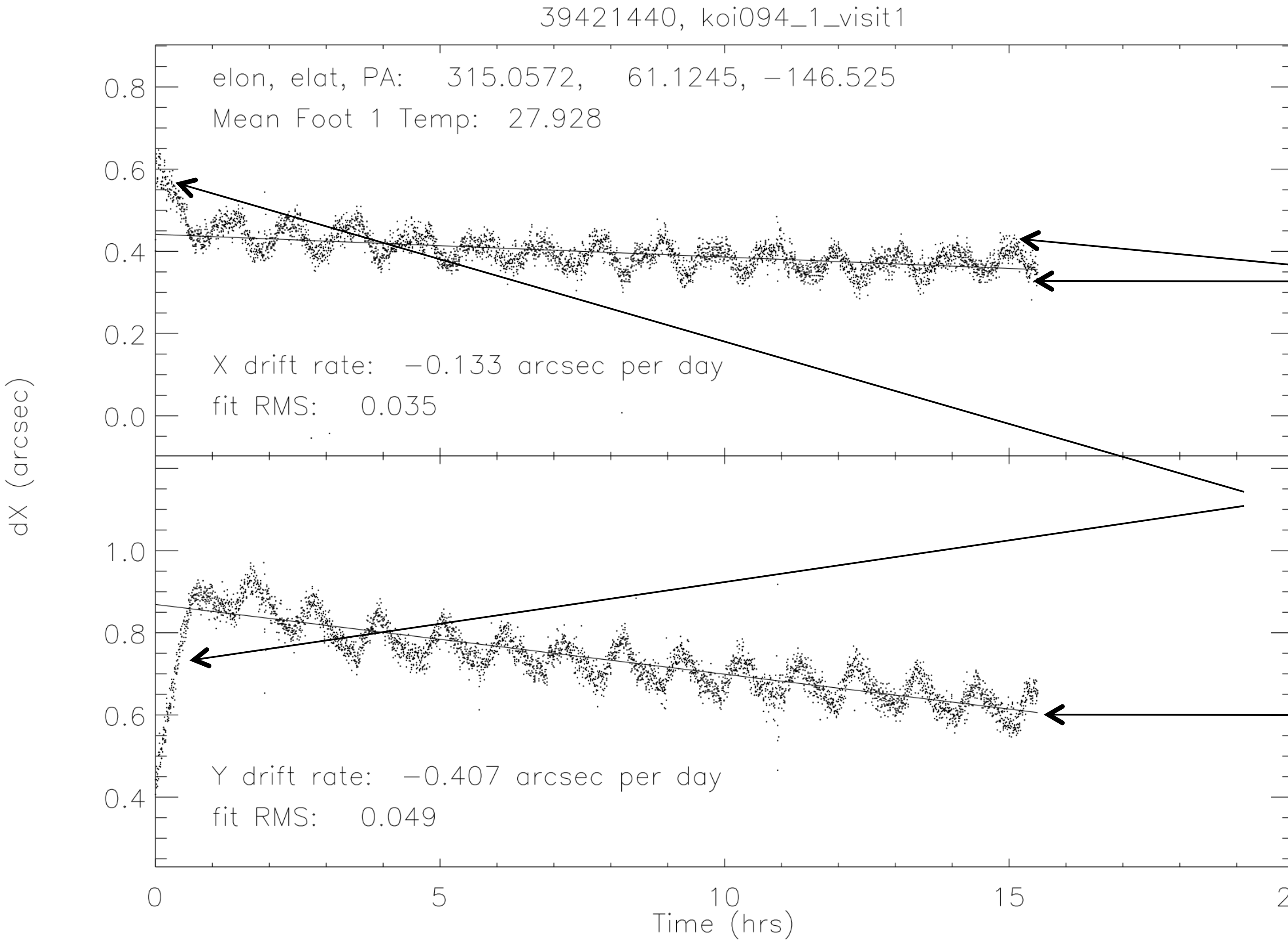
Photometric Stability



Would like to achieve a level of pointing stability that enables sub-30 ppm photometry.

Typical Centroid Behavior over Time

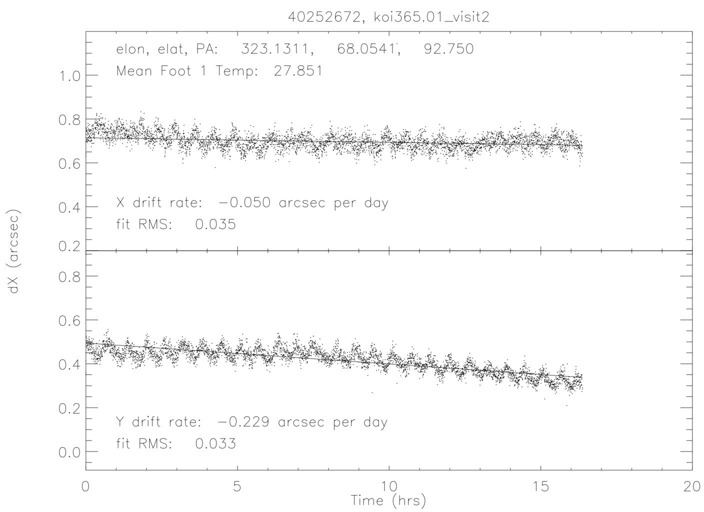


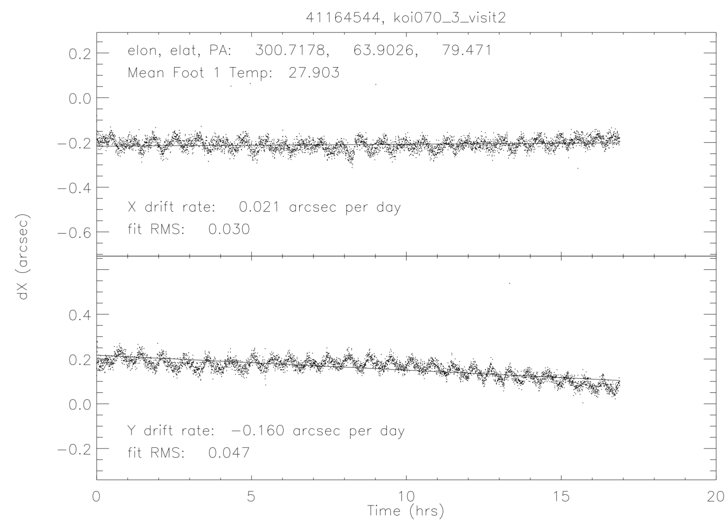
Pointing wobble or "sawtooth", with a period of 39 ± 2.5 minutes.

Initial drift, now less frequent with the use of 30-minute, pre-observation settling AORs.

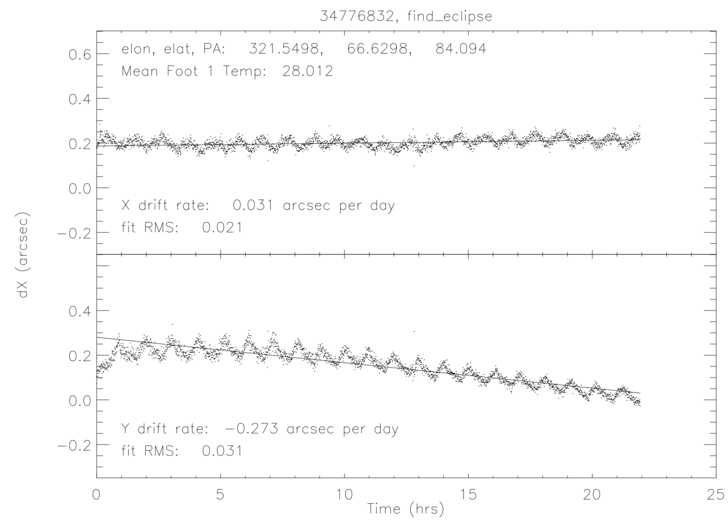
Long-term, y-pixel drift near -0.34 arcsec/day due to mismatch in frequency of velocity aberration updates by the Star Tracker and C&DH.

Pathological Cases





Many pathological cases are also seen, with non-linear behavior on time scales of 6 to 12 hours.



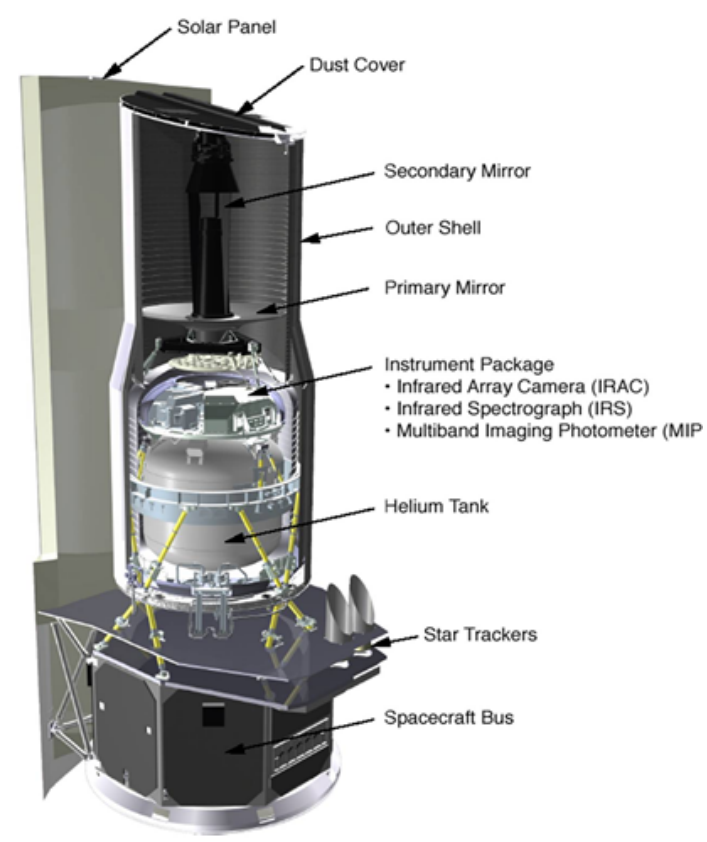
Where does Non-Linear Behavior Come From?

- Spitzer has a closed-loop pointing control system (PCS).
  - Measureable drifts on the star tracker are corrected at 0.11 Hz.

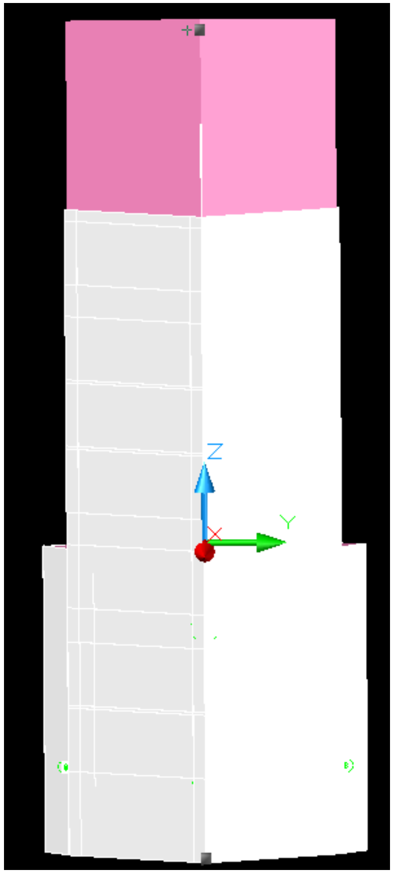
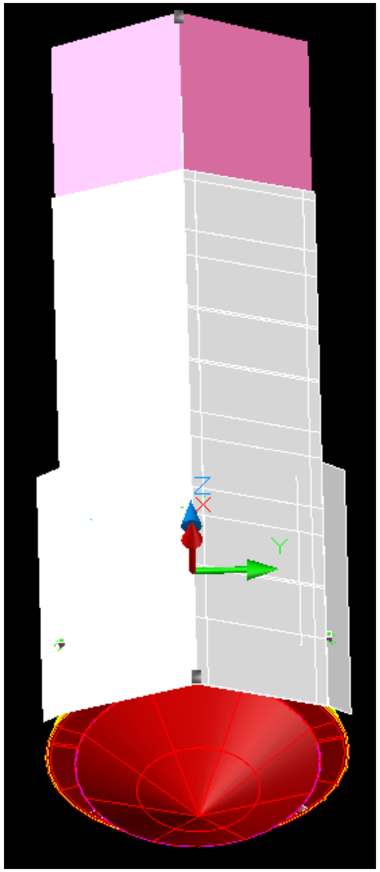
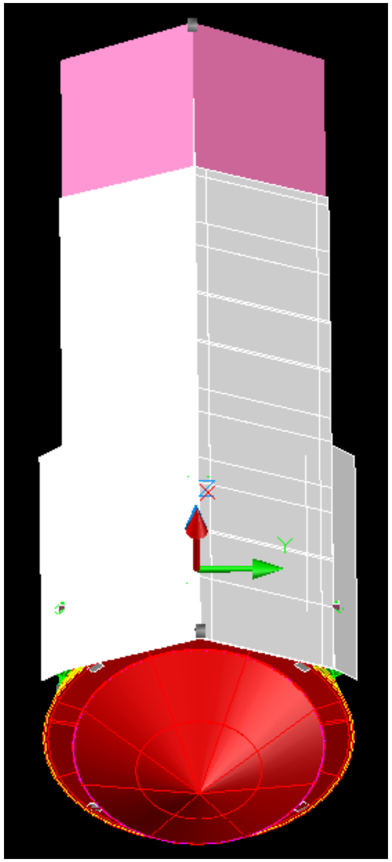
• but star trackers ≠ telescope boresight.

• so we schedule star tracker to PCRS (Pointing and Calibration Reference Sensor) calibrations before every long time series observation.

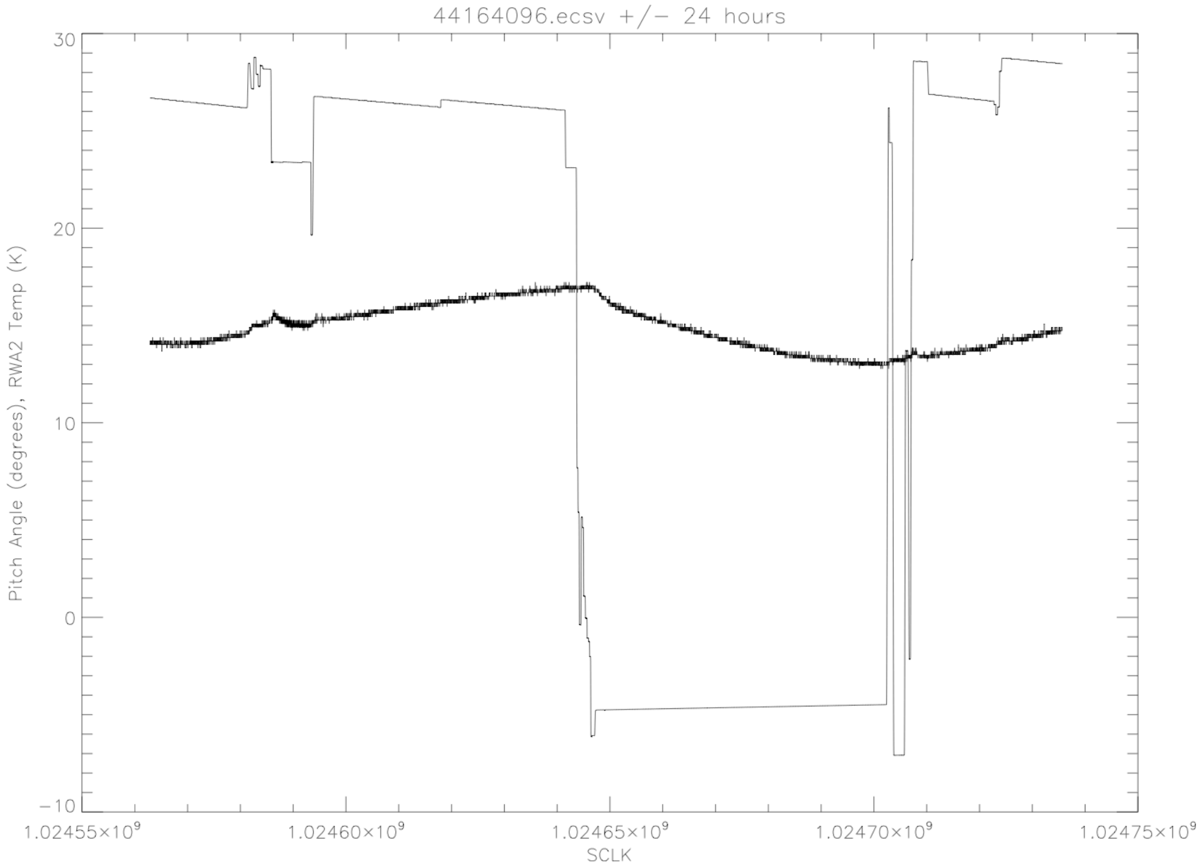
•However, any flexure between the spacecraft bus and telescope boresight *during* the observing sequence will cause an apparent motion of the target on the detectors.



Spitzer as Viewed from Sun

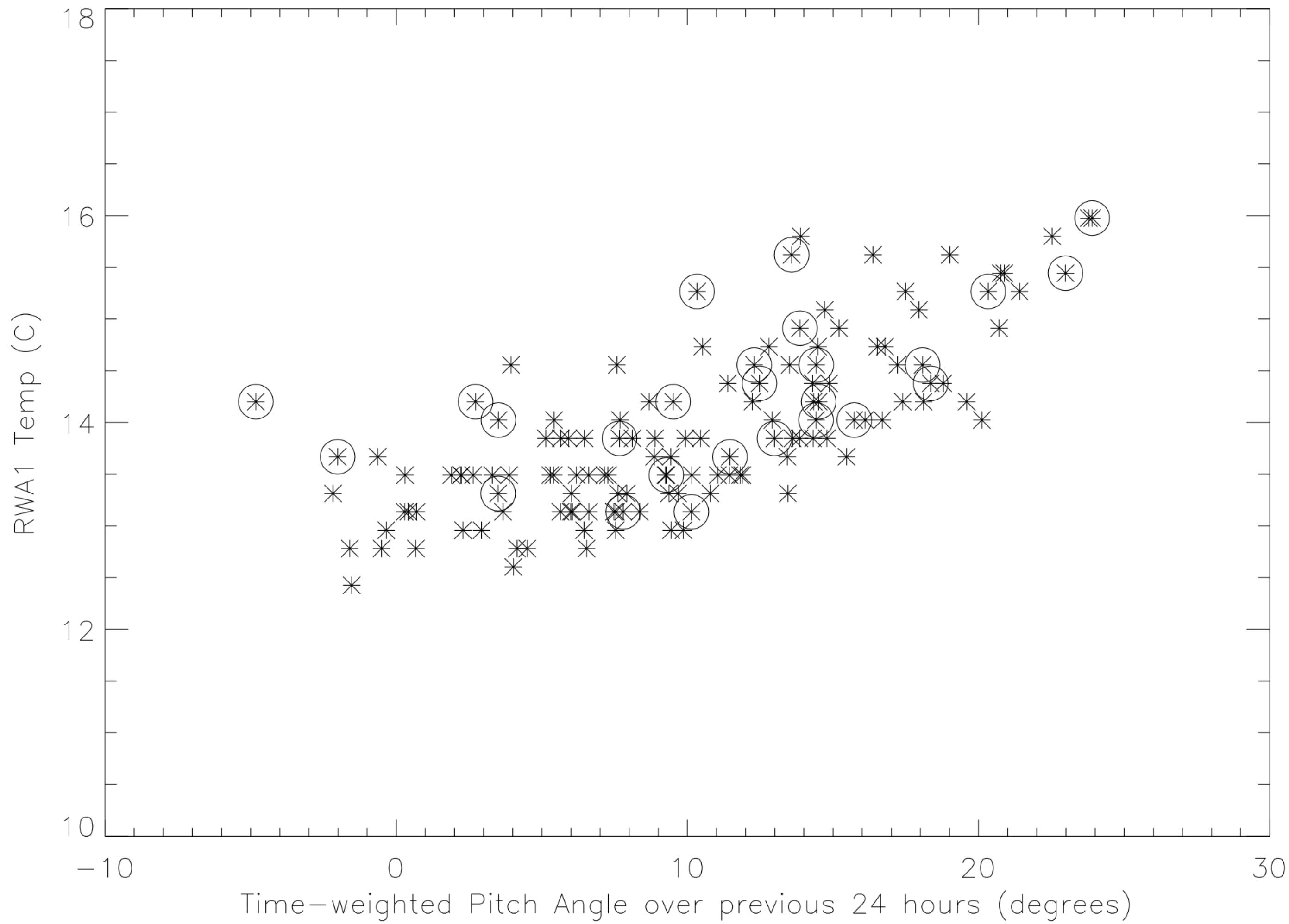
0° Pitch	30° Pitch	40° Pitch
		

Temperature vs Pitch Angle



$$T = \alpha\theta^2 \text{ for } \theta > 0,\ T = \beta T^4 \text{ for } \theta \leq 0$$

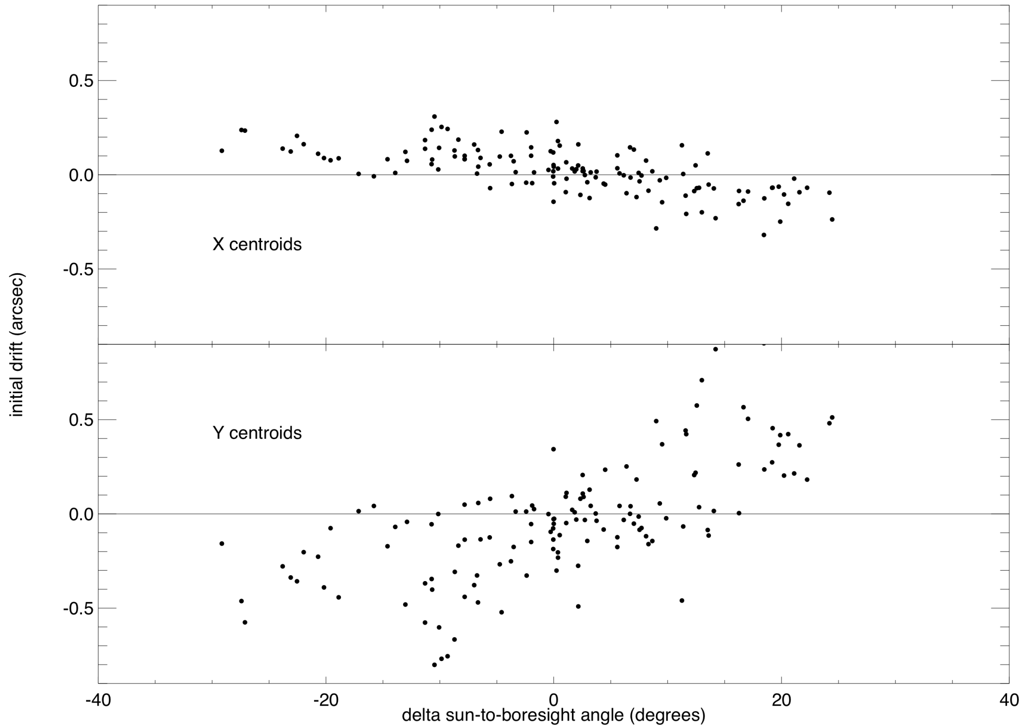
Temperature vs Pitch Angle continued



The RWA1 and RWA2 temperatures are strongly correlated with the time-weighed mean pitch angles of the telescope over the previous 24 hours.

Mean pitch angles computed over shorter periods (< 12 hours) and longer periods (> 2 days) produce weaker correlations, suggesting another thermal relaxation time scale.

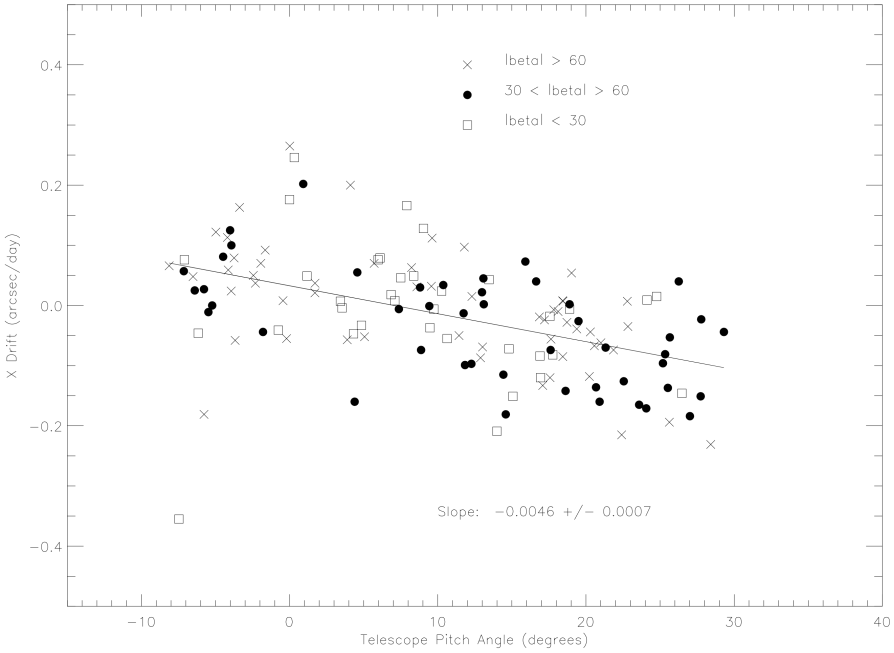
Initial Drift



Initial x and y-pixel drifts in 118 exoplanet observing sequences vs. mean change in pitch angle for targets observed during the previous half hour.

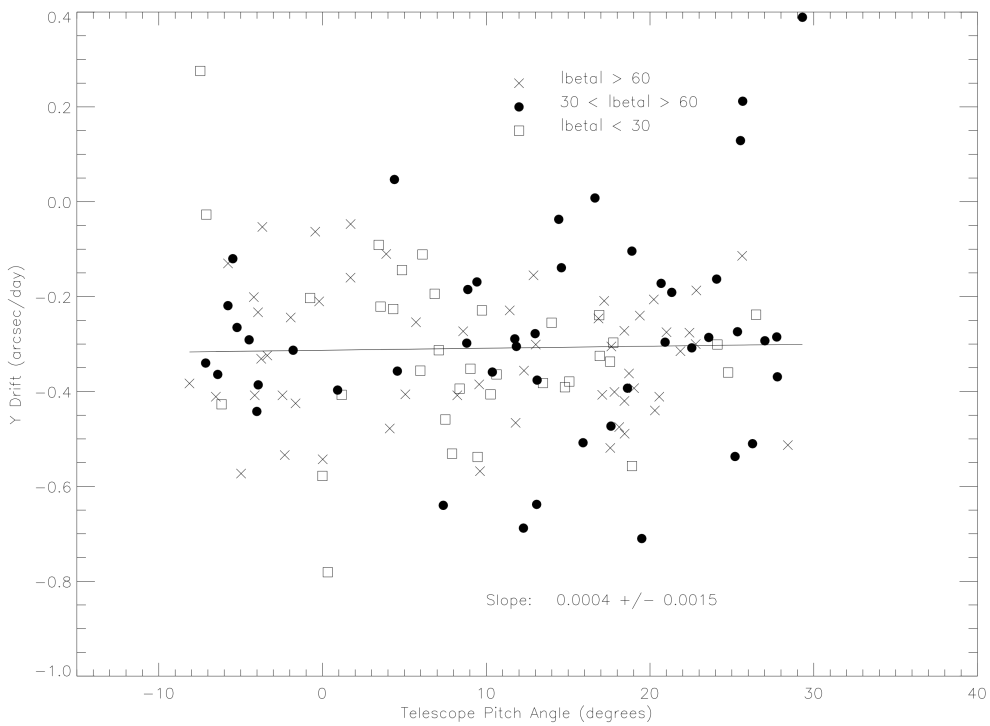
Magnitude of initial drift is clearly correlated with changes in pitch angle of the telescope.

Long-term X-pixel Drift



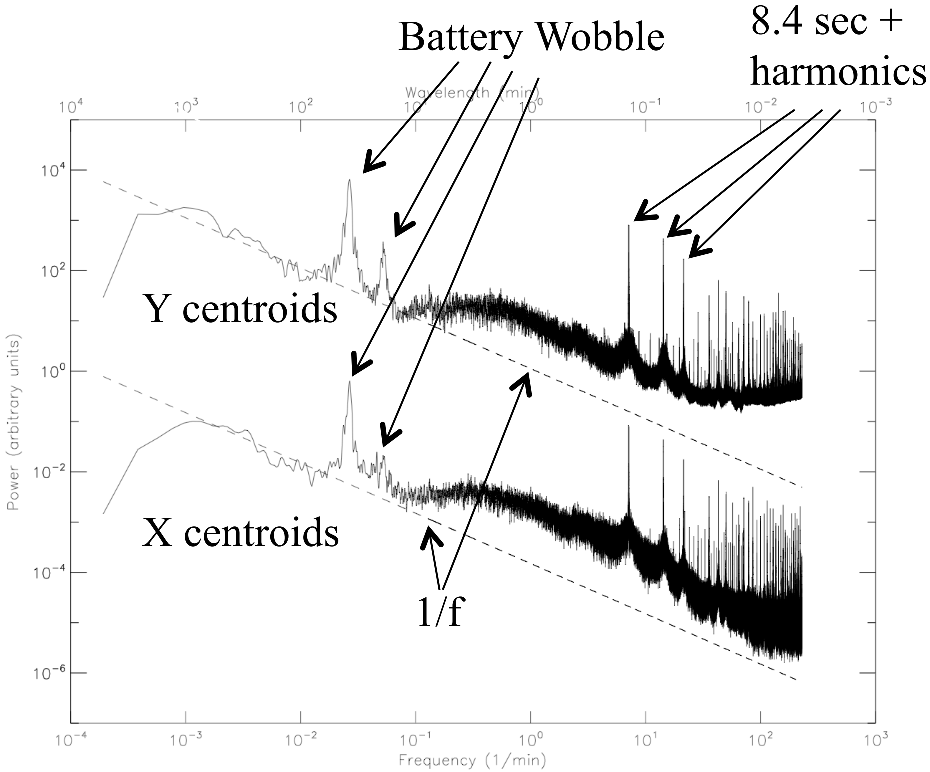
Appears to correlate with instantaneous pitch angle…

Long-term Y-pixel Drift

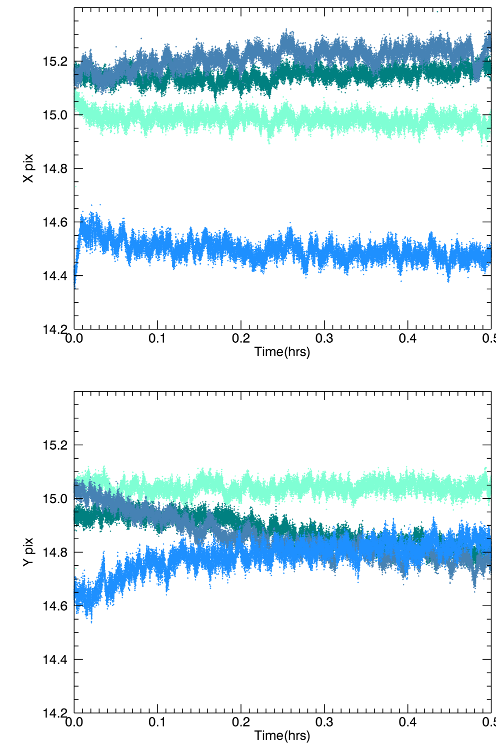


No obvious dependence on instantaneous pitch angle…

Power Spectrum



•Average power spectrum of 34 long (8-22 hours) observing sequences.
 -departs from ideal 1/f behavior at higher frequencies.



Centroid motion @ 0.02 sec sampling.
 - correlated undulations with periods 2-3 minutes and amplitudes 0.03 - 0.1 arcsec ➔ low frequency jitter.

Summary

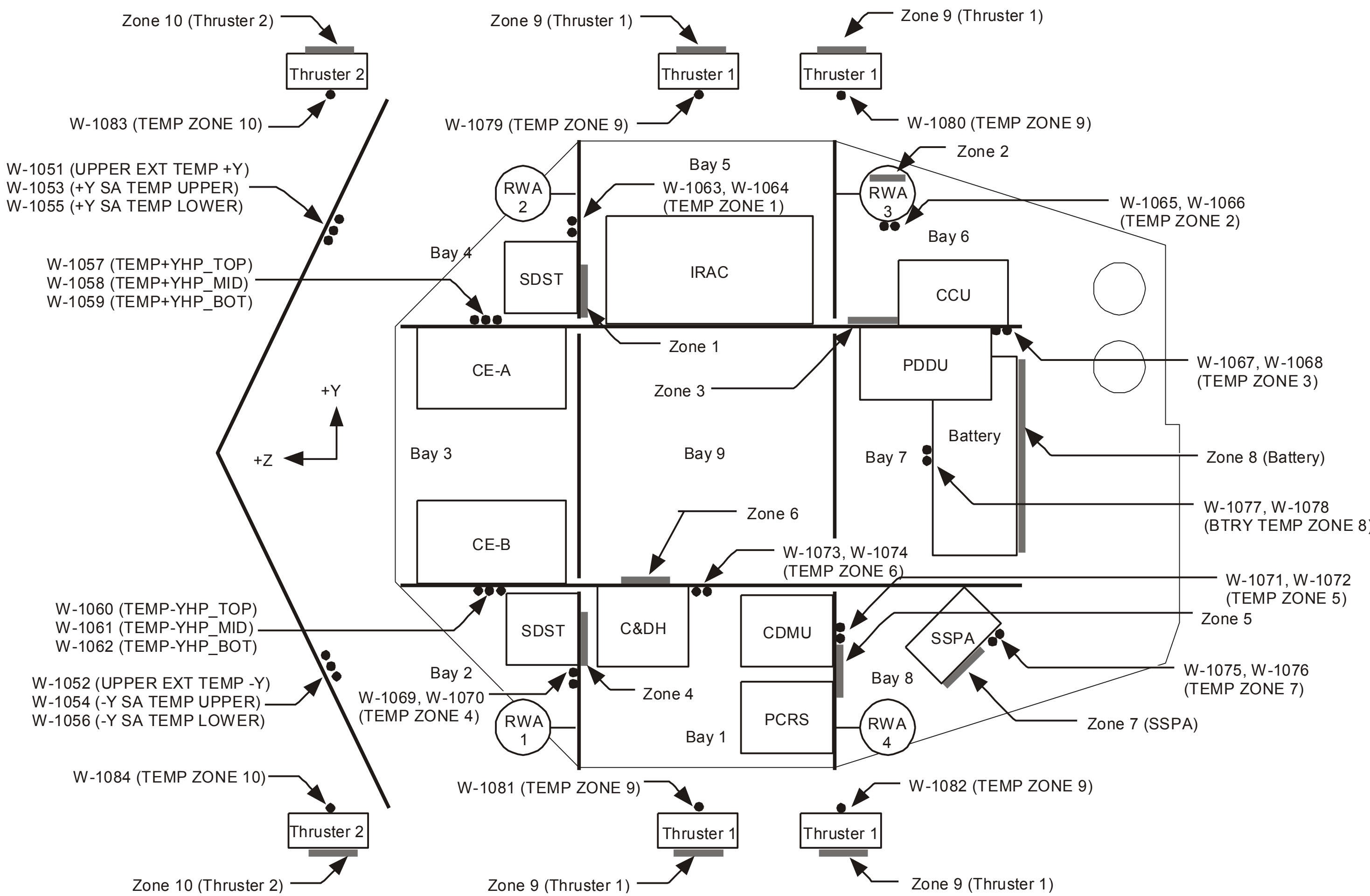
- Long-term drift remains the most problematic issue for time series photometry.
- Magnitude and direction of long-term drift may be a consequence of thermal relaxation on a time scale of ~ 1 day.
  - *It is not generally feasible to arrange observing schedules so as to reduce net pitch offsets on 24 hours time scales.*
- Flight software changes to correct the dominant Y-pixel drift are essentially ruled out at this point due to cost and risk.
- A work-around may be possible but will require testing.
- Analysis of pitch/temperature effects and jitter continue…

Take Away Numbers

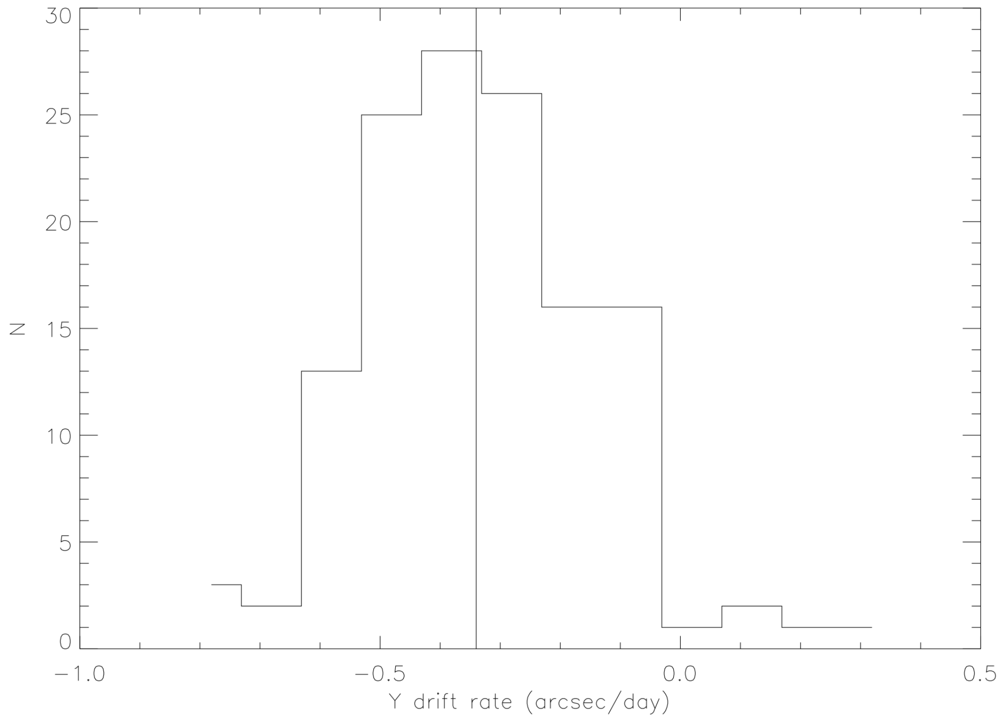
Pointing Effect	Characteristic Amplitude	Characteristic Time Scale
Accuracy	0.07 arcsec	N/A
Wobble	0.07 arcsec	~40 minutes
Initial Drift	0.5 arcsec	~30 minutes
Long-term Drift	0.3 arcsec	~1 day
Low frequency jitter	0.07 arcsec	~2 minutes
High frequency jitter	0.03 arcsec	< 0.02 seconds

Backup Slides

Heater and Temperature Sensor Locations



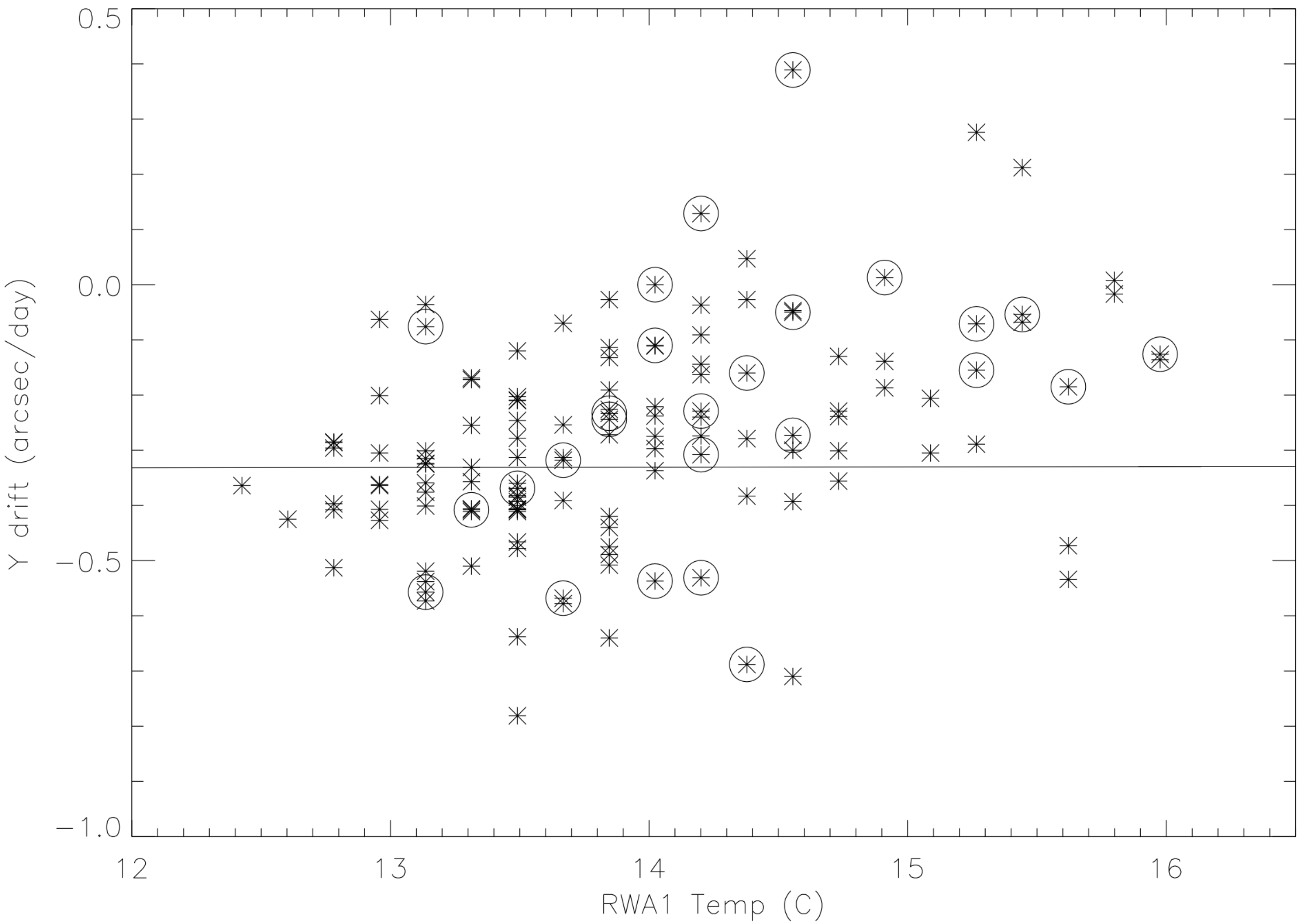
Drift Distribution



At present, we can hope to use mitigation techniques to shift the mean of the distribution towards zero, thus reducing the number of high drift cases (|dy/dt| > 0.3 arcsec/day).

The width of the distribution, and the occurrence of higher-order wobbles has yet to be understood.

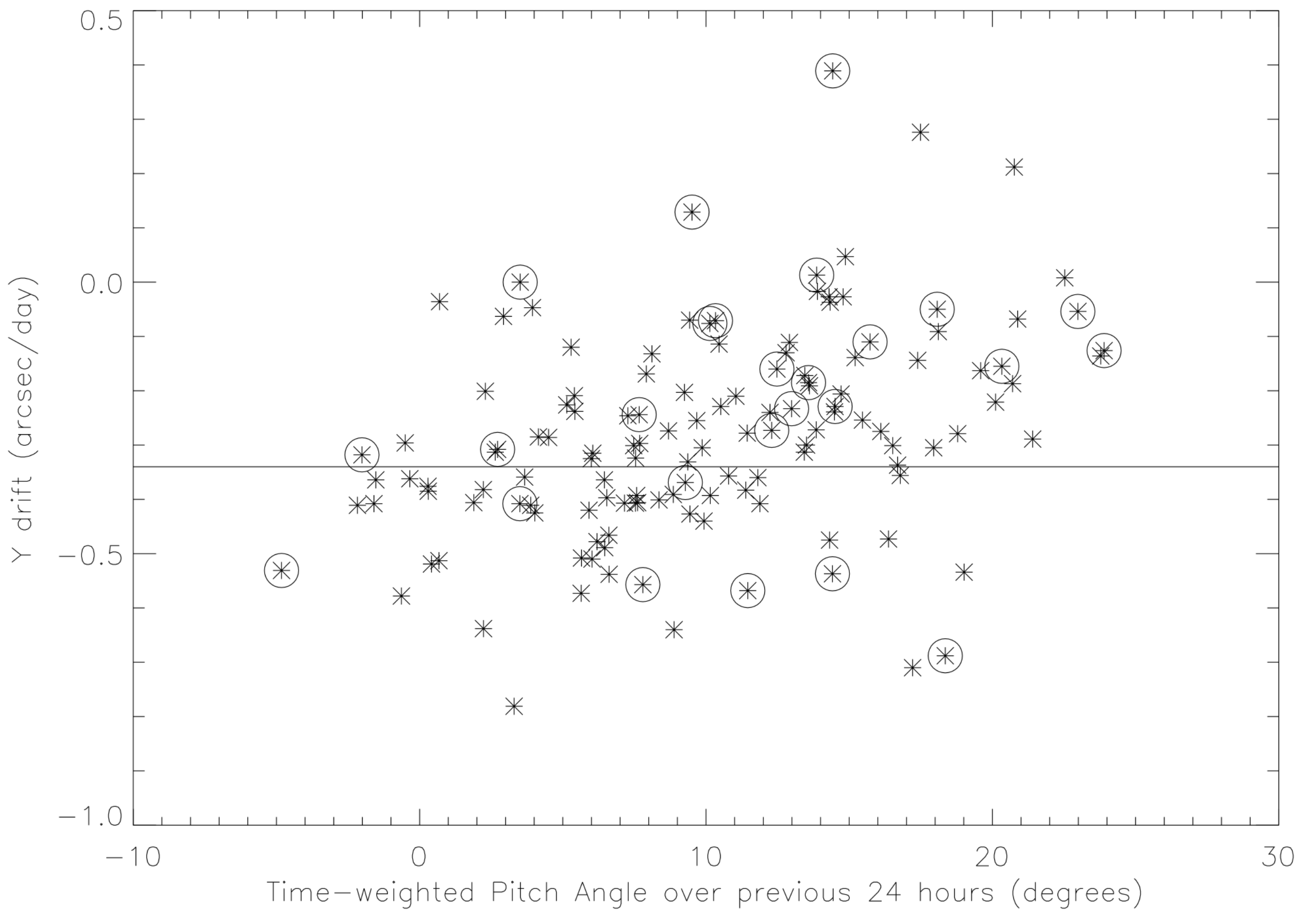
How about Temperature?



Y-pixel drift shows a rough correlation with the temperature measured at the RWA1 and RWA2 (but not RWA3) at the beginning of the AOR.

Circled points are "pathological" cases, with higher-order, long term wobbles.

A Direct Correlation?



Weak…