Driftscan FFI analysis

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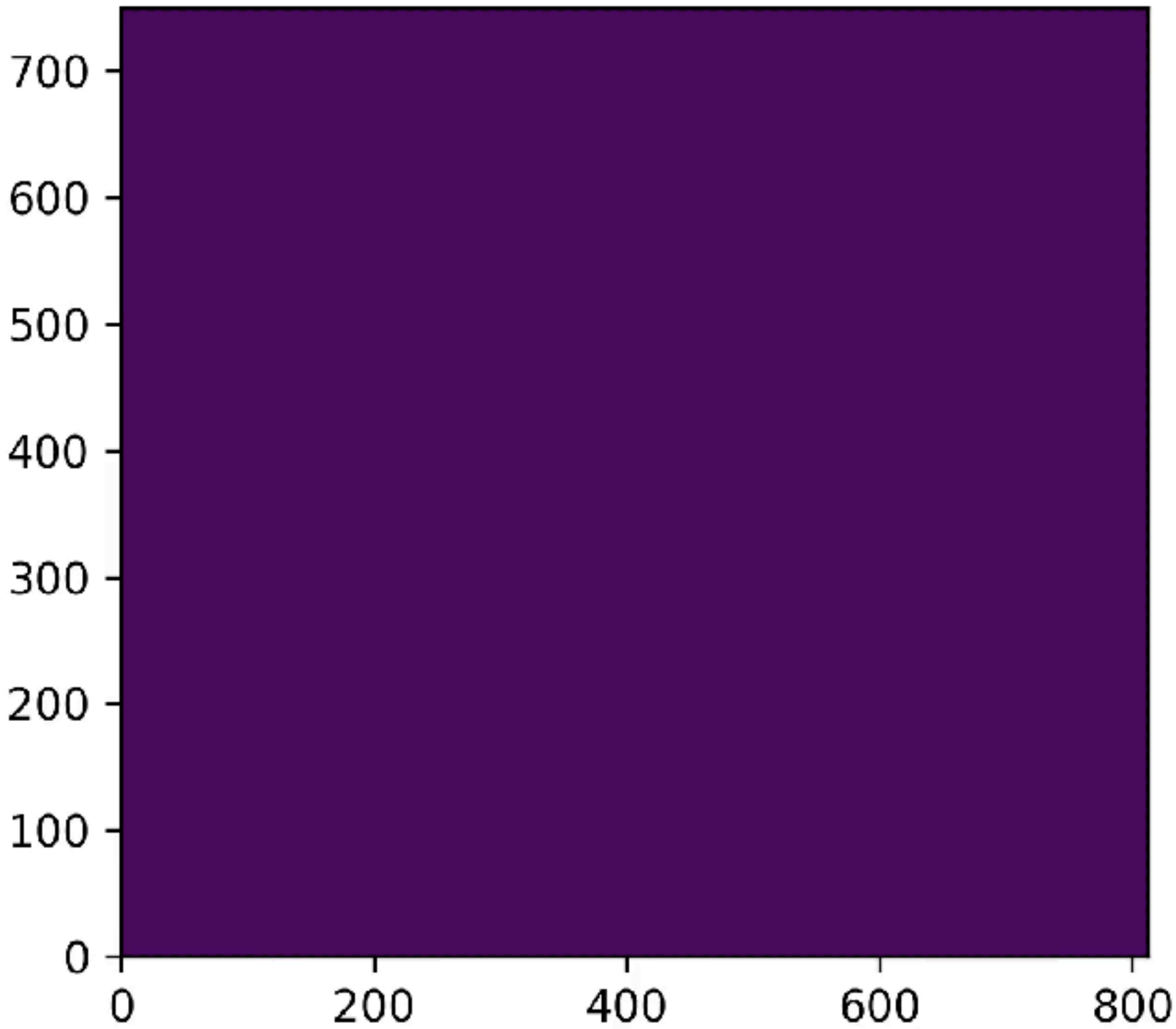
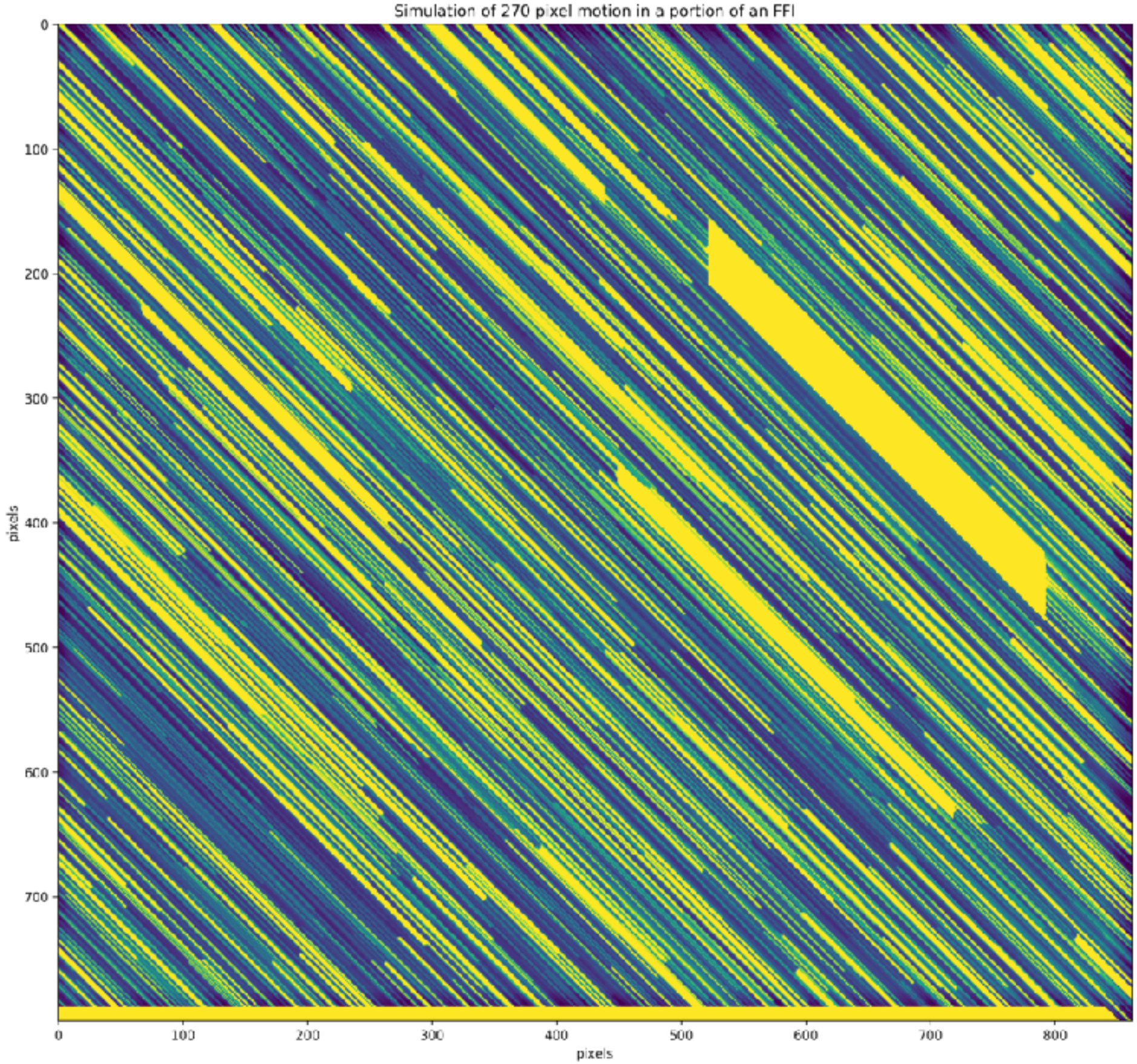
Driftscanning is an experimental data collection mode in which the telescope collects a Full Frame Image (FFI) while the telescope is drifting in (TWSDDL).



This animation simulates the data collection process with expected 0.5deg/hr. Only the final frame is telemetered back to Earth, yielding overlapping star trails.



Only the final frame is telemetered back to Earth, yielding overlapping star trails.

Motivation for FFI experiment

1. Pixel sensitivity calibration (flat field correction)

2. Astrophysical variation on very short (~ten seconds) timescales

3. Joint modeling of faint stars (e.g. Trappist-1) with underlying calibration *(advanced)*

Operational advantages of driftscan FFIs

1. It doesn't matter where you point.
2. Delivers usable data over a wide range of angular motions (*e.g.* low-fuel conditions).
3. Does not require any "heroic efforts"-- no new operational modes: just normal FFI sequence.
4. Can be carried out during periods of extended indecision (TWSM, post-ARB but pre-TWSDDL).
5. **Avoids wasting precious pre-allocated DSN time.**
6. Has the potential to enhance all Kepler data ever taken, including from the prime mission.

Operational limitations of driftscan FFIs

1. Not better than a regular science campaign.
2. Data analysis will be unusual.
3. Still costs DSN time that could have been allocated to other NASA missions.
4. It's not clear how pixel calibration changes in time (ask D. Caldwell about SPSDs).

A short pilot program was carried out on May 10-11, 2018, to evaluate the feasibility of driftscan FFI operations. Driftscan FFIs were collected during the K2 Campaign 17 (C17) Deep Space Network (DSN) downlink, after all C17 science data had been safely telemetered and spare DSN time remained.

Anticipated questions (easy)

1.How many FFIs were taken?

2.What were the delay-times between acquisitions?

3.What was the delivered motion?

4.Was the motion primarily in (x,y), or was there rotation also?

5.Was the delivered motion smooth?

6.What is the distribution of S/N per pixel?

7.Did saturated stars ruin the exposures?

8.Can you associate star trails from one FFI with the next FFI?

Anticipated questions (harder)

9.Where was Kepler pointing during the exposures?

10.What was the stellar density?

11.What is the effect of shutterless exposure?

12.What was the angular acceleration of the telescope as a function of time?

13.Do you observe PSF variation?

14.Do you observe short-timescale astrophysical variability?

Anticipated questions (research project)

15. Is the variance of star trails consistent with flat field effects?

16. For what fraction of pixels do you have sufficient S/N to compute a revised flat field?

17. If that subset is finite, how does the revised flat field compare to the lab-measured flat field?

18. Do you observe chromatic-dependence in PSF variation?

How many FFIs were taken?

What were the delay-times between acquisitions?

kplr2018131024020_ffi-orig.fits

kplr2018131032646_ffi-orig.fits

kplr2018131041344_ffi-orig.fits

kplr2018131094047_ffi-orig.fits

kplr2018131130639_ffi-orig.fits

Year **DOY** **HH MM SS**

We took 5 FFIs.

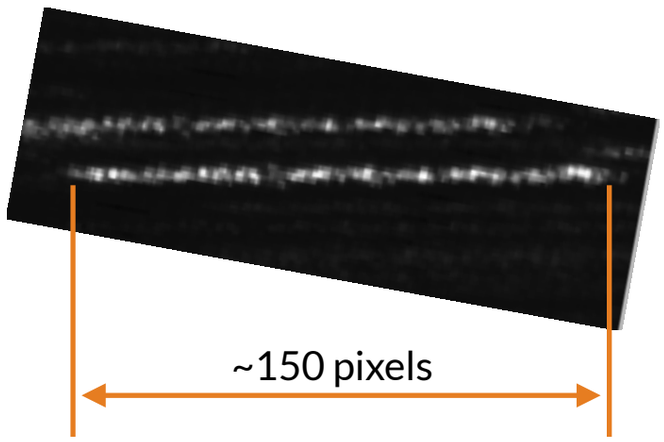
The exposure time is 30 minutes, so the delay between the end of one and beginning of the next ranges from 16 minutes to ~5 hours.

The save to SSR command takes ~15 minutes. (Marcie Smith, Doug Caldwell priv. comm.)

FFI num	delay between (min)
1	0
2	16
3	17
4	297
5	176

What was the delivered motion?

FFI num	Channel	length *(pixels)*	motion *(deg/hr) =("/sec)*
1	41	155	0.350
1	53	152	0.346
2	41	157	0.356
2	53	156	0.354
3	41	158	0.359
3	53	157	0.357
4	41	144	0.326
4	53	141	0.319
5	41	156	0.353
5	53	153	0.347



conversion factors
4"/pixel
29.4 minute exposure time

The delivered motion was **~0.35 degrees/hour**, slightly less than the coarse 0.5 degrees/hour prediction.
The fourth FFI had about 10% slower motion than the others.

What was the delivered motion?

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1	41	155	0.350
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4	53	141	0.319
5	41	156	0.353
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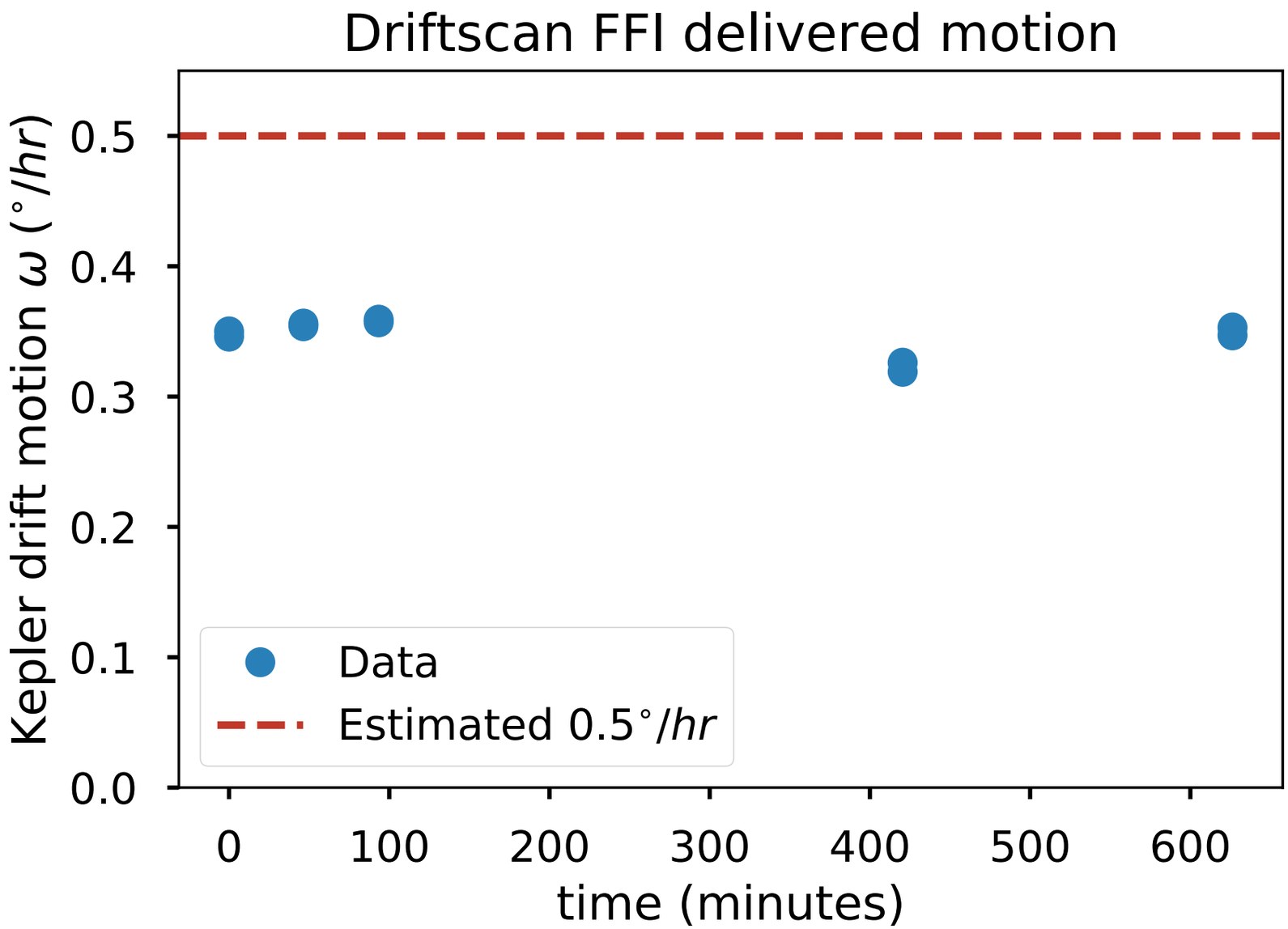
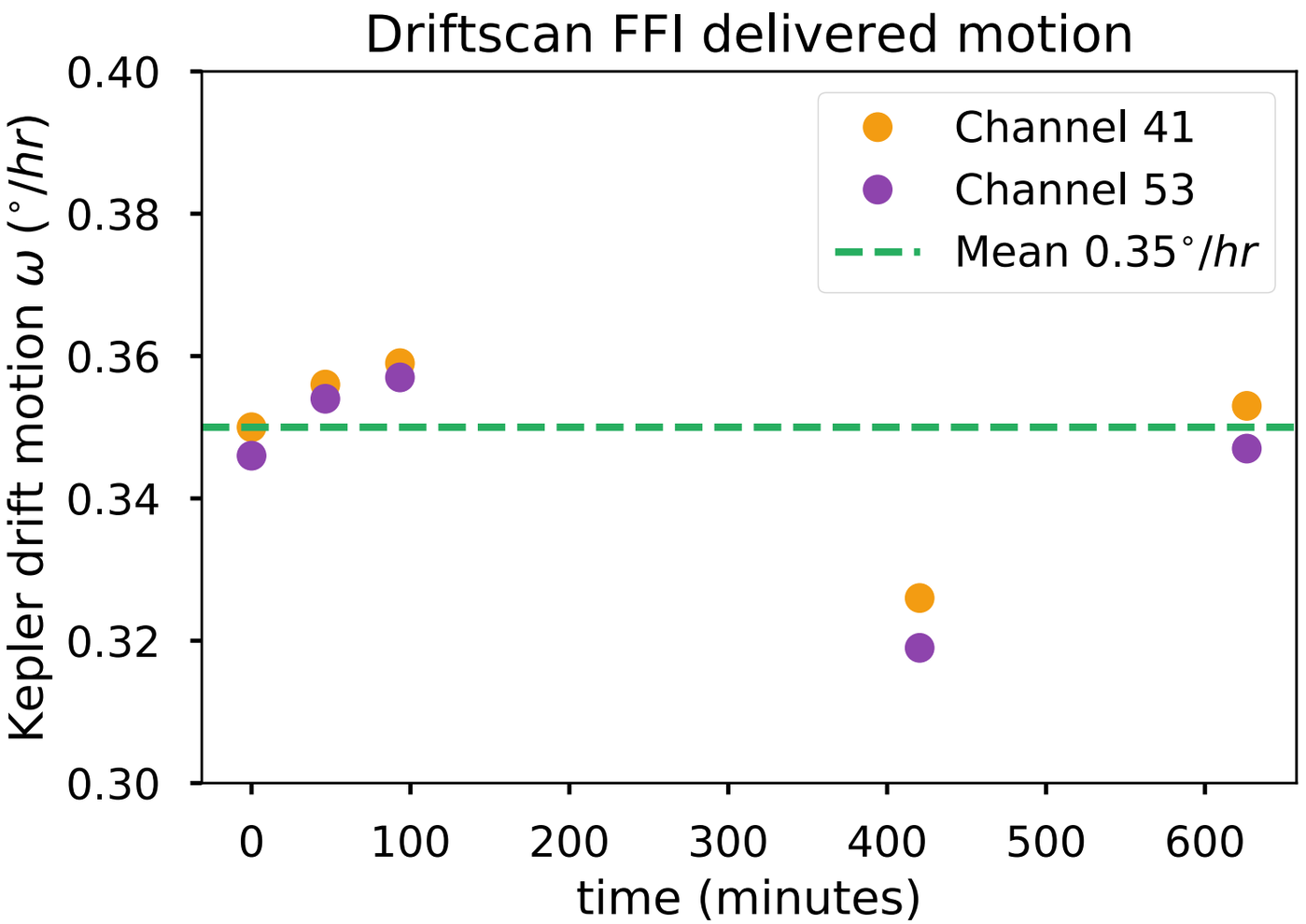
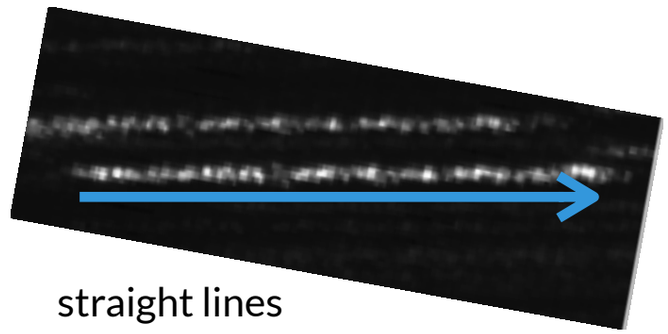


The delivered motion was **~0.35 degrees/hour**, slightly less than the coarse 0.5 degrees/hour prediction.
The fourth FFI had about 10% slower motion than the others.

Was the motion primarily in (x,y), or was there rotation also?





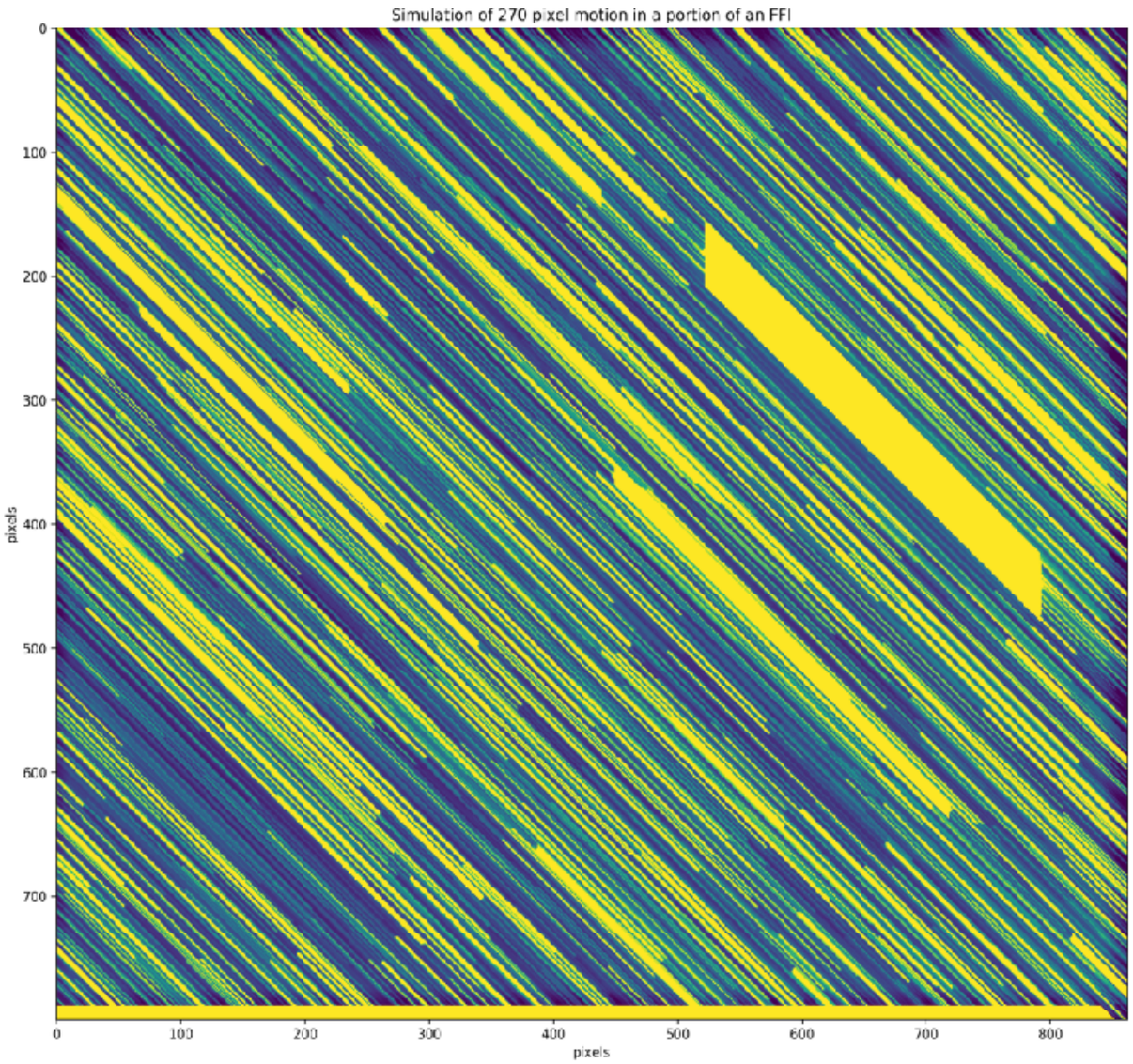
The driftscan line segments look mostly like lines, not curved like sickles, suggesting that most of the motion was from linear telescope pointing drift, and not rotation around the boresight.

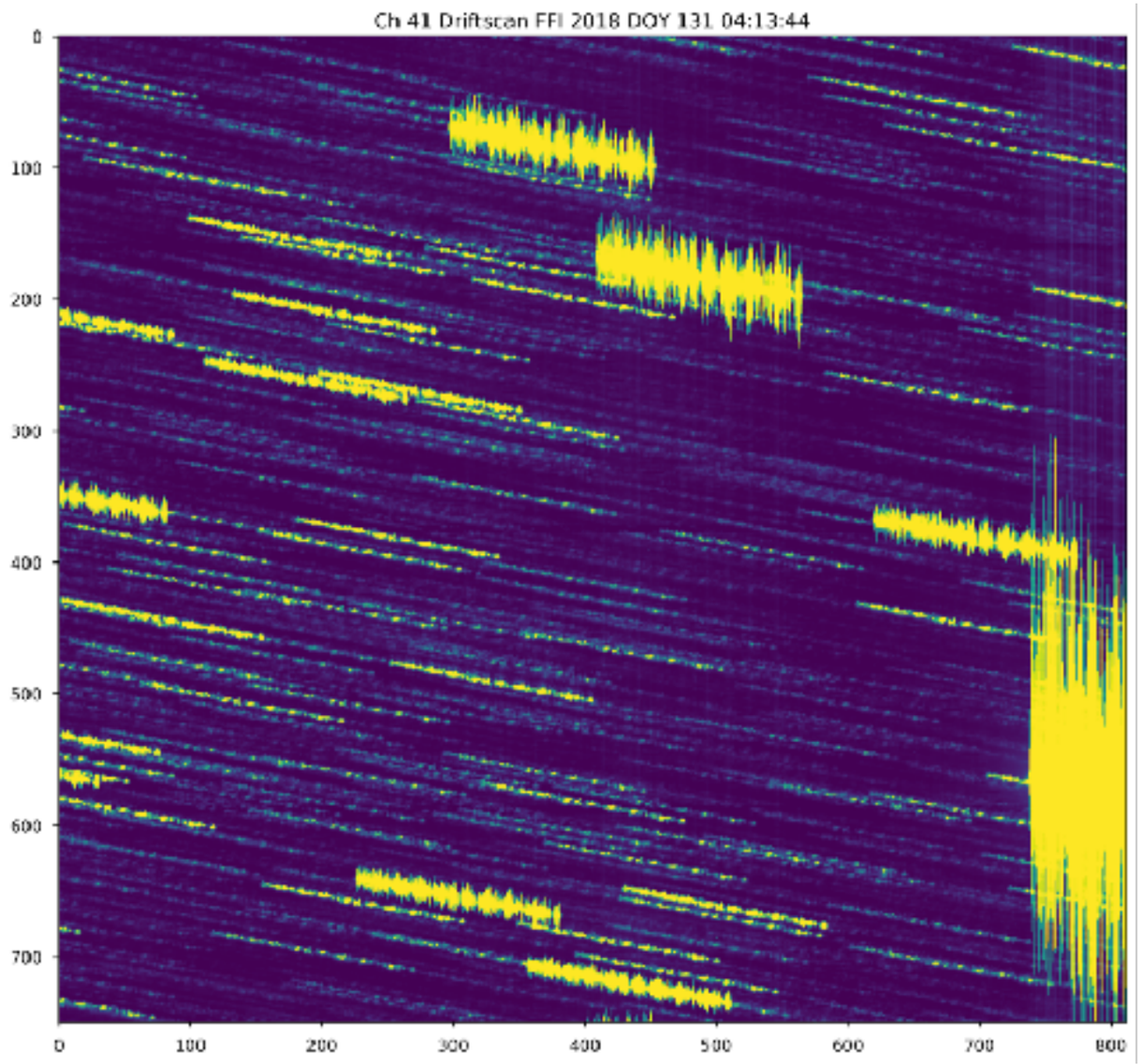
The driftscan line segments have about the same length from center to edge. Channel 41, near the boresight center, possesses routinely longer line segments than Channel 53. This effect can be caused by either gradual rotation about an axis outside of the telescope FOV, or different PSF sizes, leading to biased line-segment estimation.

Was the delivered motion smooth? *No!*

<u>Naive prediction:</u>
Smooth star trails from constant motion.

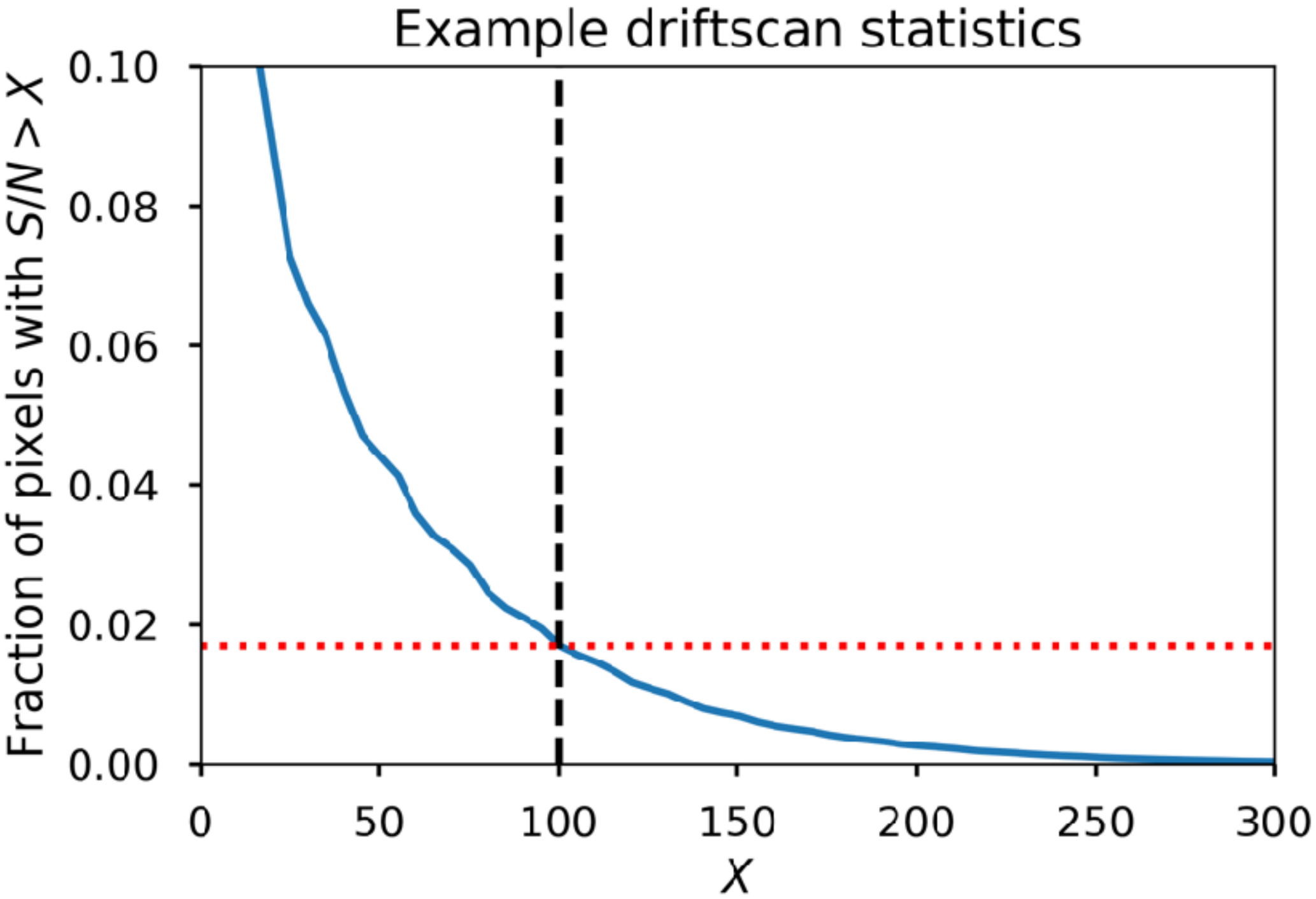
<u>Observed:</u>
Jumpy star trails from jittery motion.





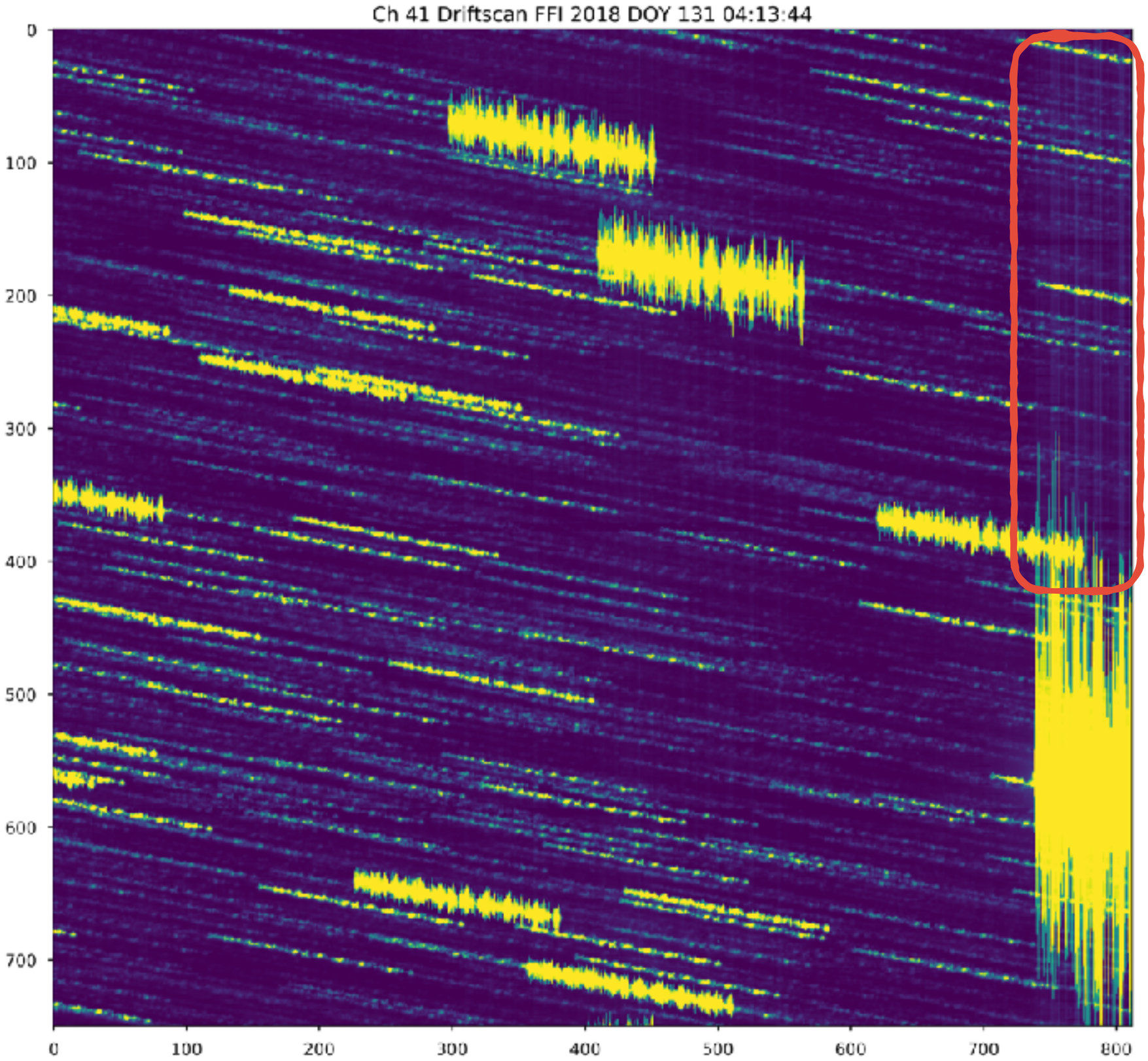
It looks like all star trails share the identical jumpy motion pattern, suggesting that the pattern arises from common telescope differential motion. The pattern could also arise from differential telescope heating and dynamic optical aberrations and tip/tilt.

What is the distribution of S/N per pixel?



About 1.7% of pixels have S/N 100 or greater.

Did saturated stars ruin the exposures? **No.**



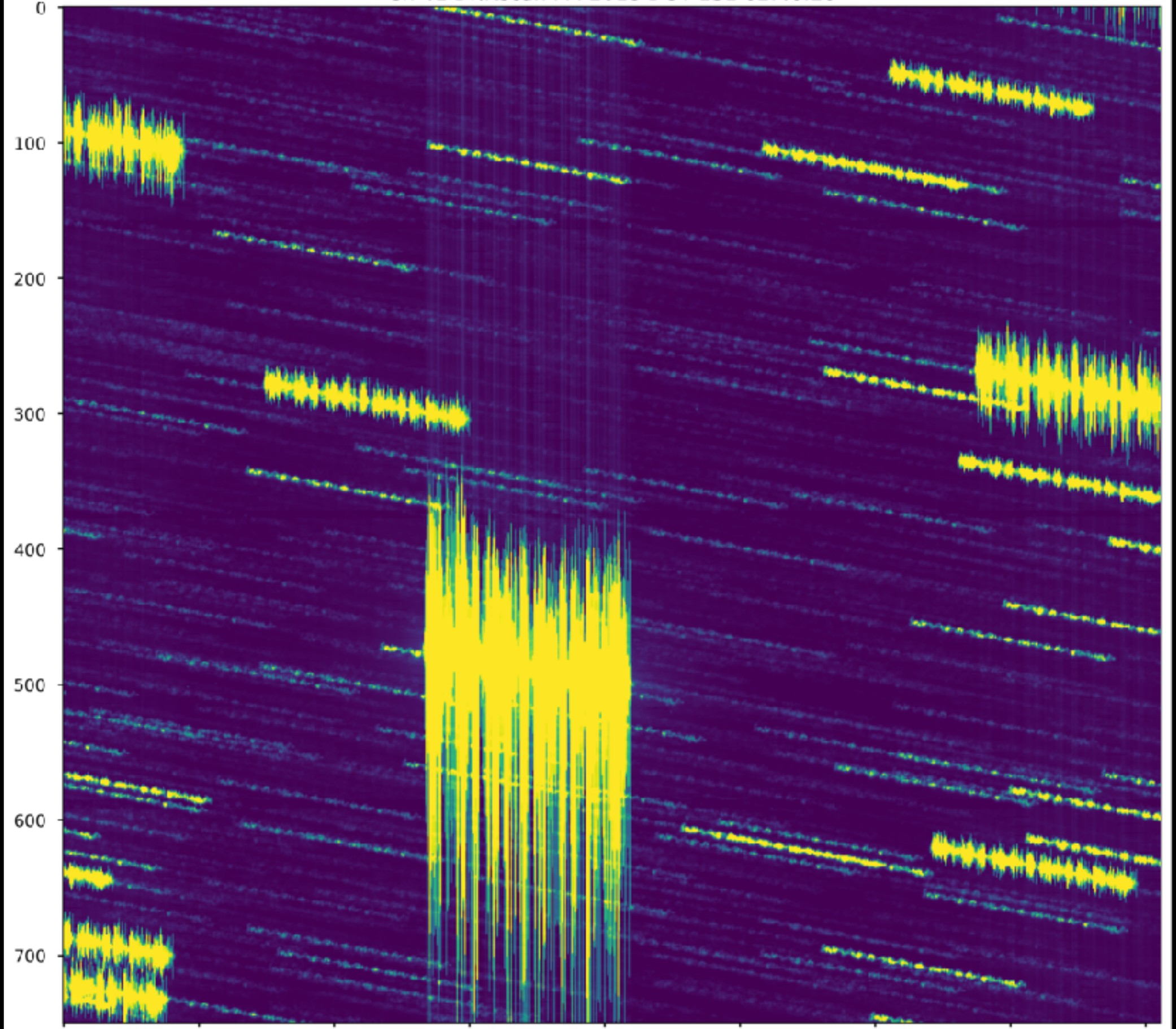
Some streaking,
but no irretrievable information loss

Worry was that saturated stars in collateral smear data would make it impossible to determine the flux in pixels above or below the saturated stars.

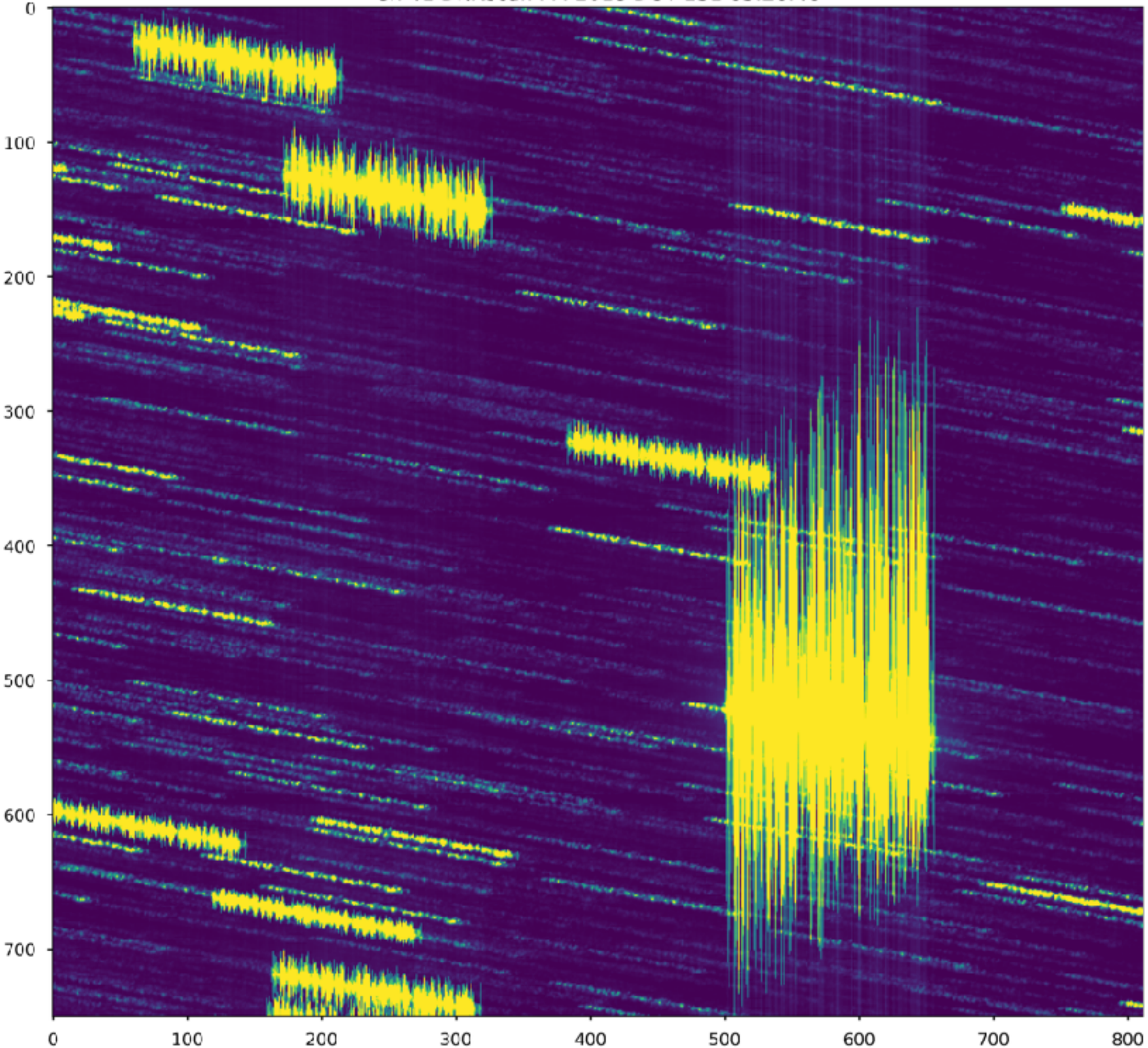
Can you associate star trails from one FFI with the next FFI?

Yes.

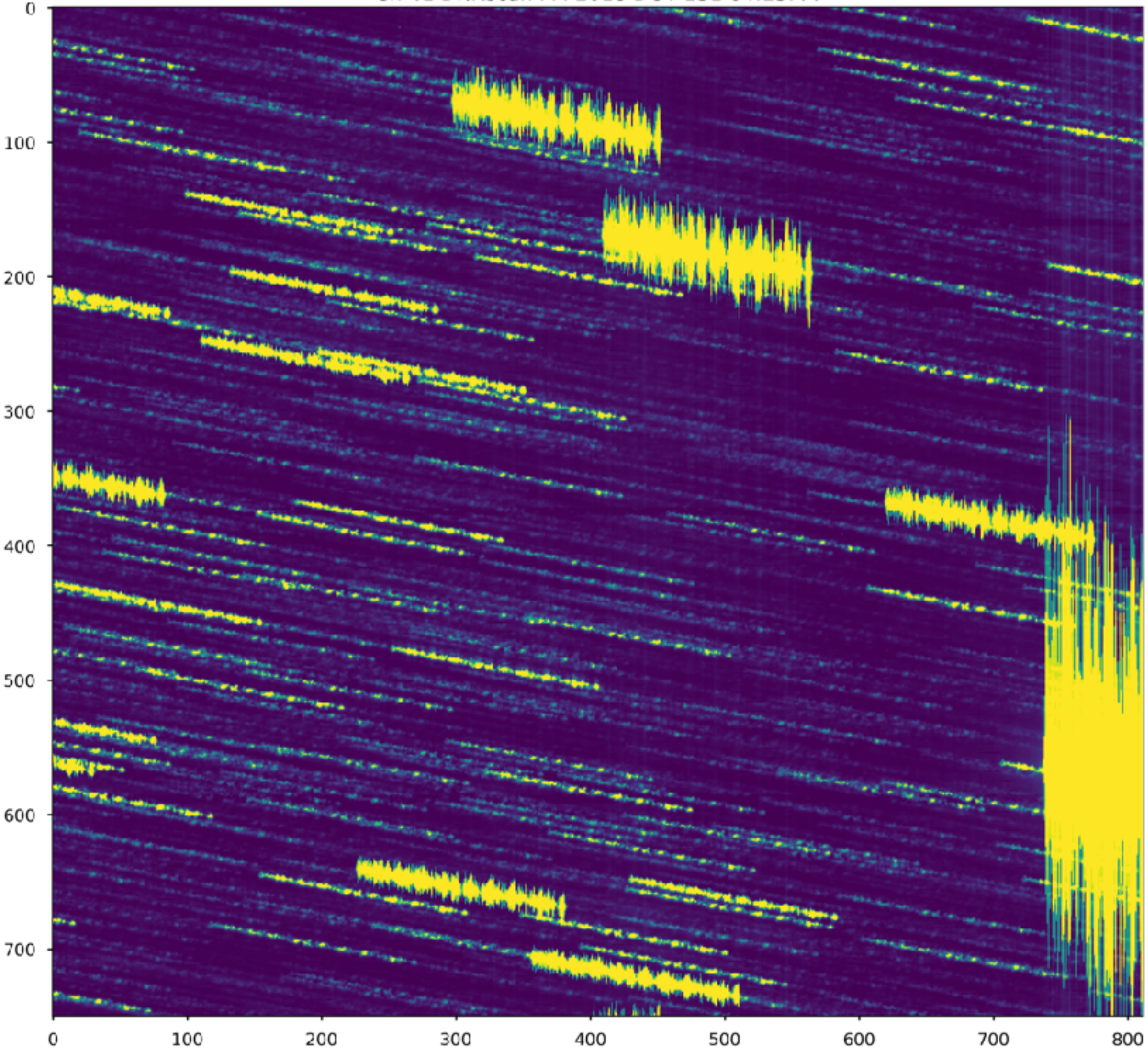
Ch 41 Driftscan FFI 2018 DOY 131 02:40:20



Ch 41 Driftscan FFI 2018 DOY 131 03:26:46



Ch 41 Driftscan FFI 2018 DOY 131 04:13:44



Answer to questions (easy)

1.How many FFIs were taken? **5**

2.What were the delay-times between acquisitions? **16 min - 5 hrs**

3.What was the delivered motion? **~0.35 deg/hr**

4.Was the motion primarily in (x,y), or was there rotation also? **primarily in (x,y)**

5.Was the delivered motion smooth? **No!**

6.What is the distribution of S/N per pixel? ~1.7% of pixels have S/N 100 or more

7.Did saturated stars ruin the exposures? **No.**

8.Can you associate star trails from one FFI with the next FFI? **Yes.**

Anticipated questions (harder)

9. Where was Kepler pointing during the exposures? **TBD...**

10. What was the stellar density? **TBD...**

11. What is the effect of shutterless exposure? **TBD, see Next slide**

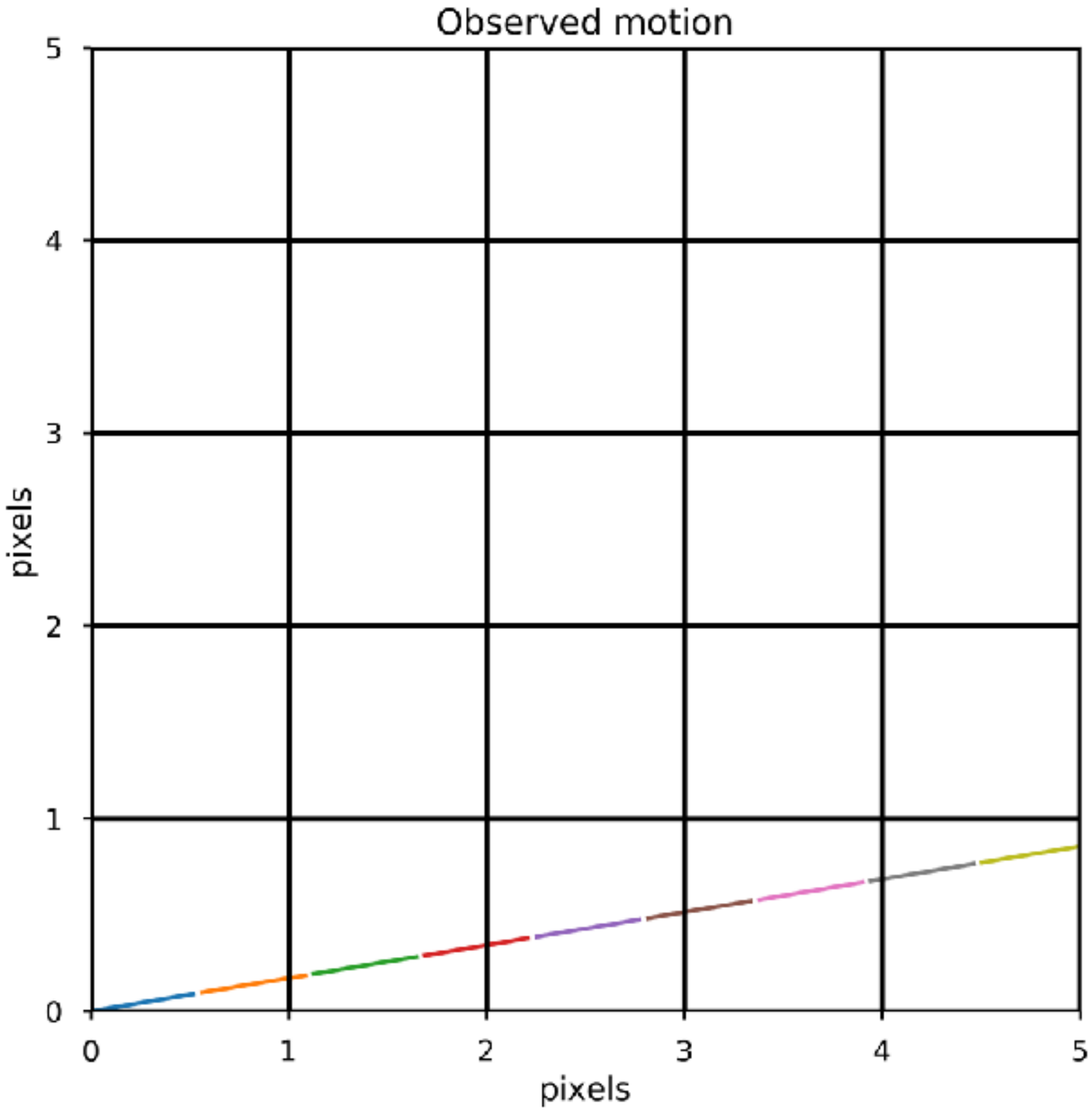
12. What was the angular acceleration of the telescope as a function of time? **Next slide + 1**

13. Do you observe PSF variation? **TBD...**

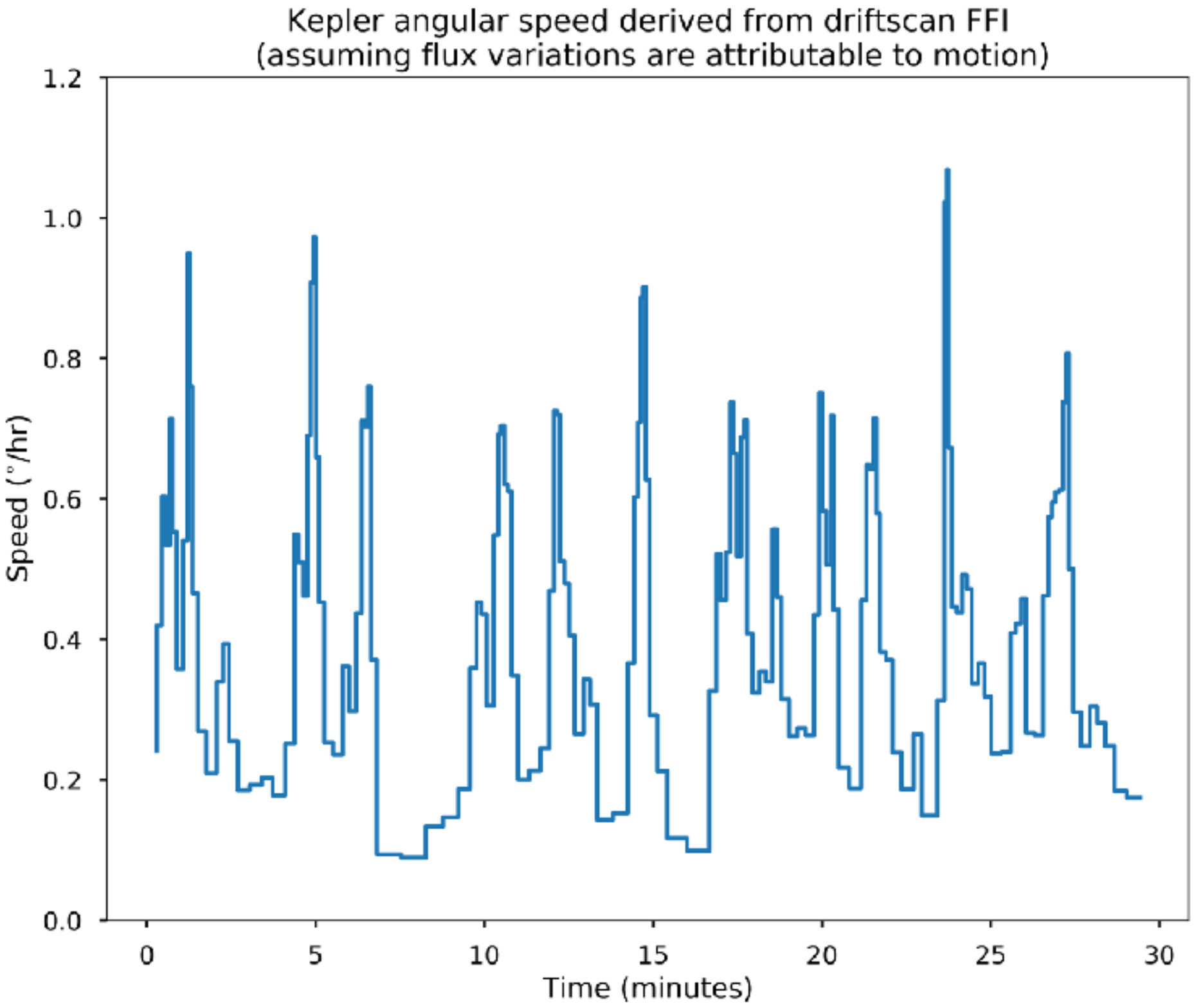
14. Do you observe short-timescale astrophysical variability? **TBD...**

What is the effect of shutterless exposure?

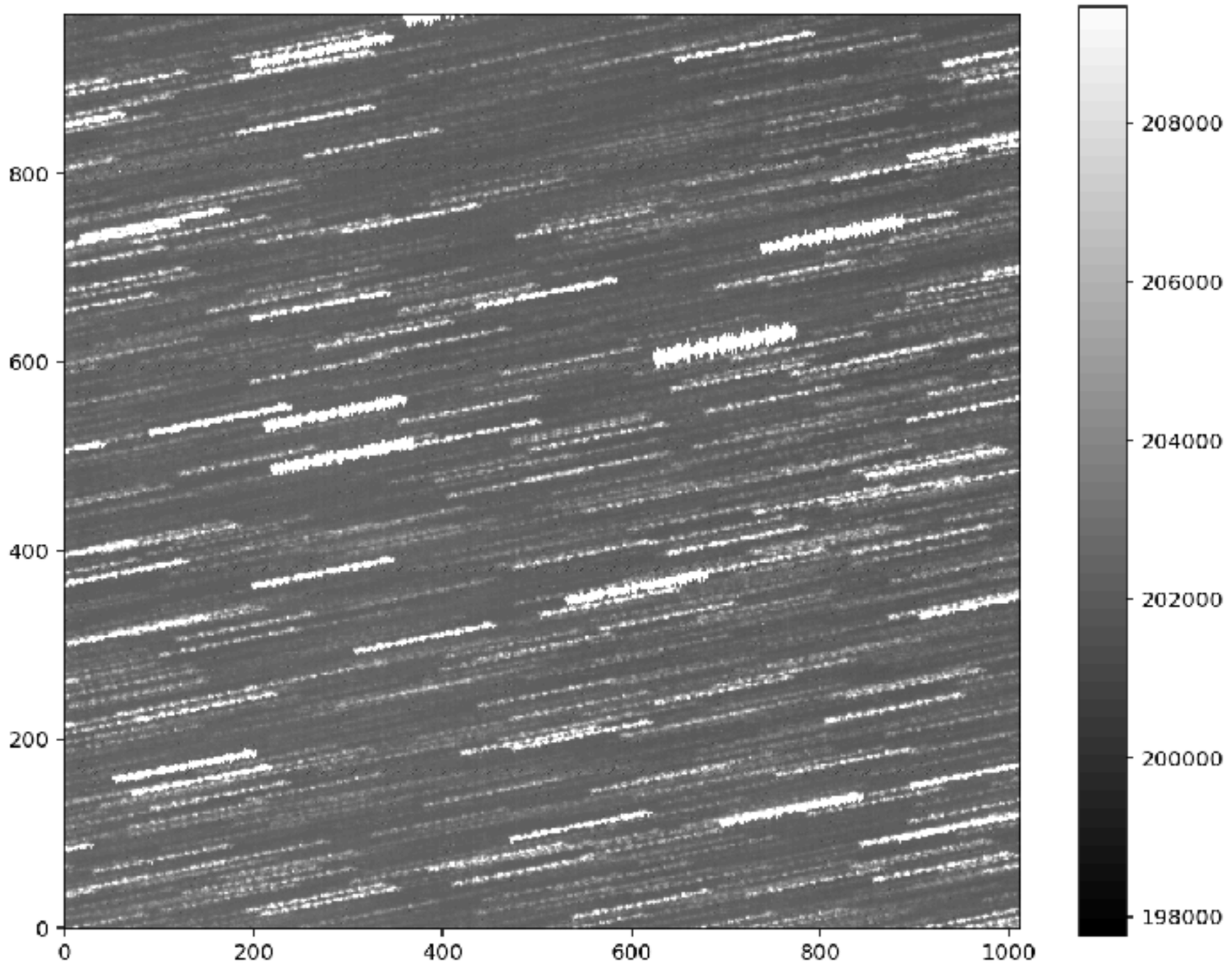
We're still not certain how the shutterless readout interplays with drift



What was the angular acceleration of the telescope as a function of time?

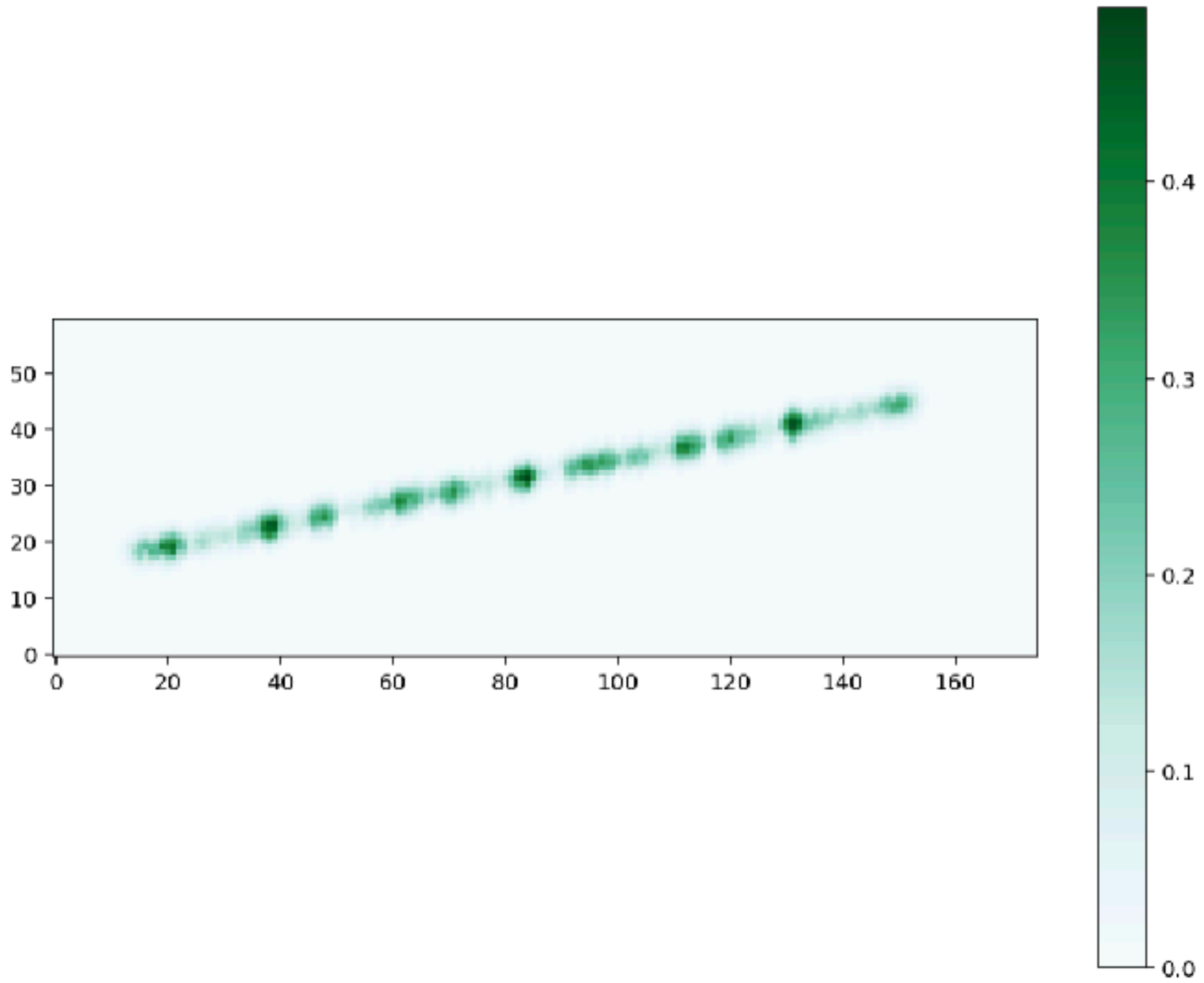


Methods



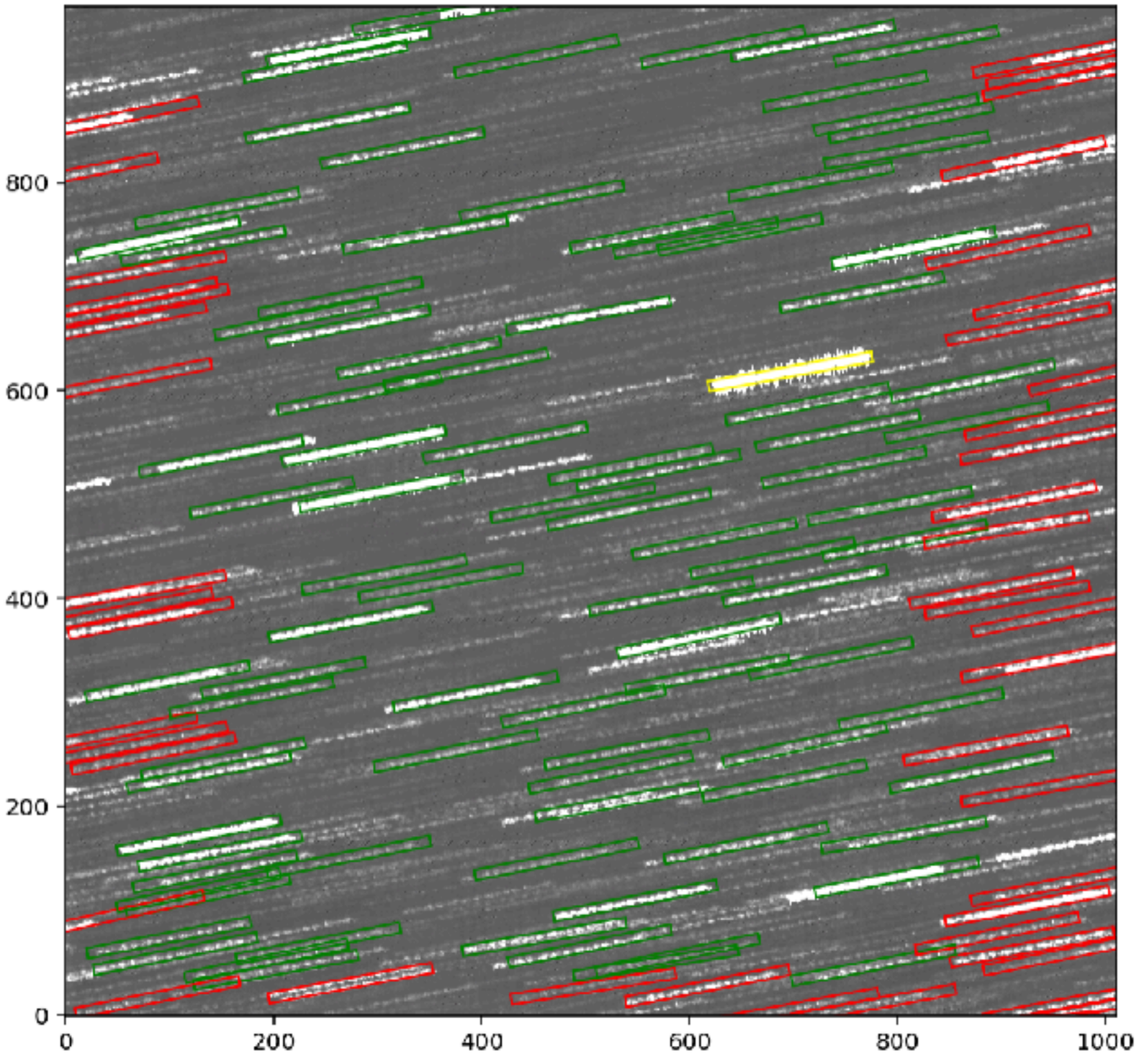
Goal: Get aperture photometry on the star trails.

Methods



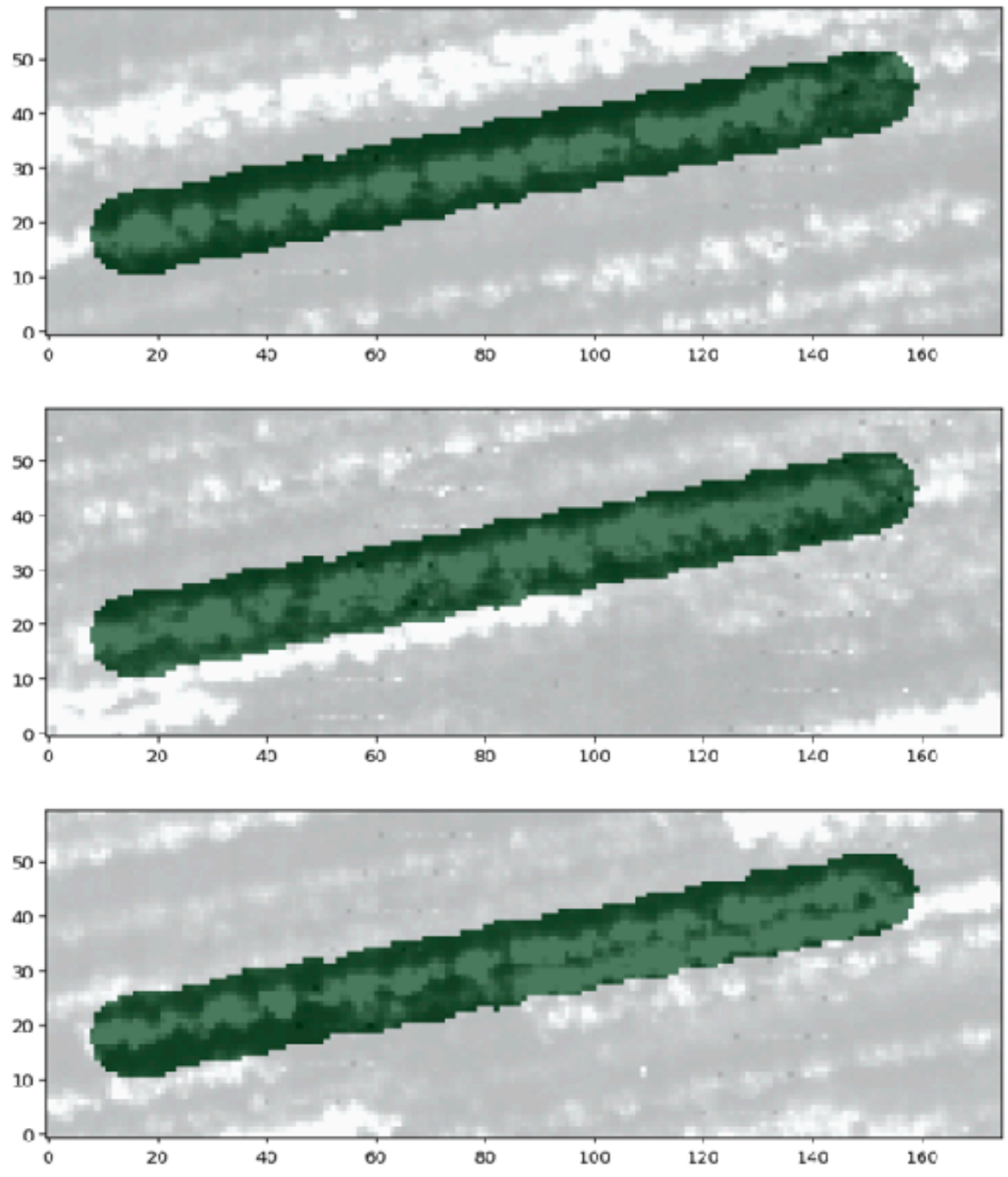
Assemble a convolution kernel from a high S/N, unsaturated, isolated, filtered star trail.

Methods



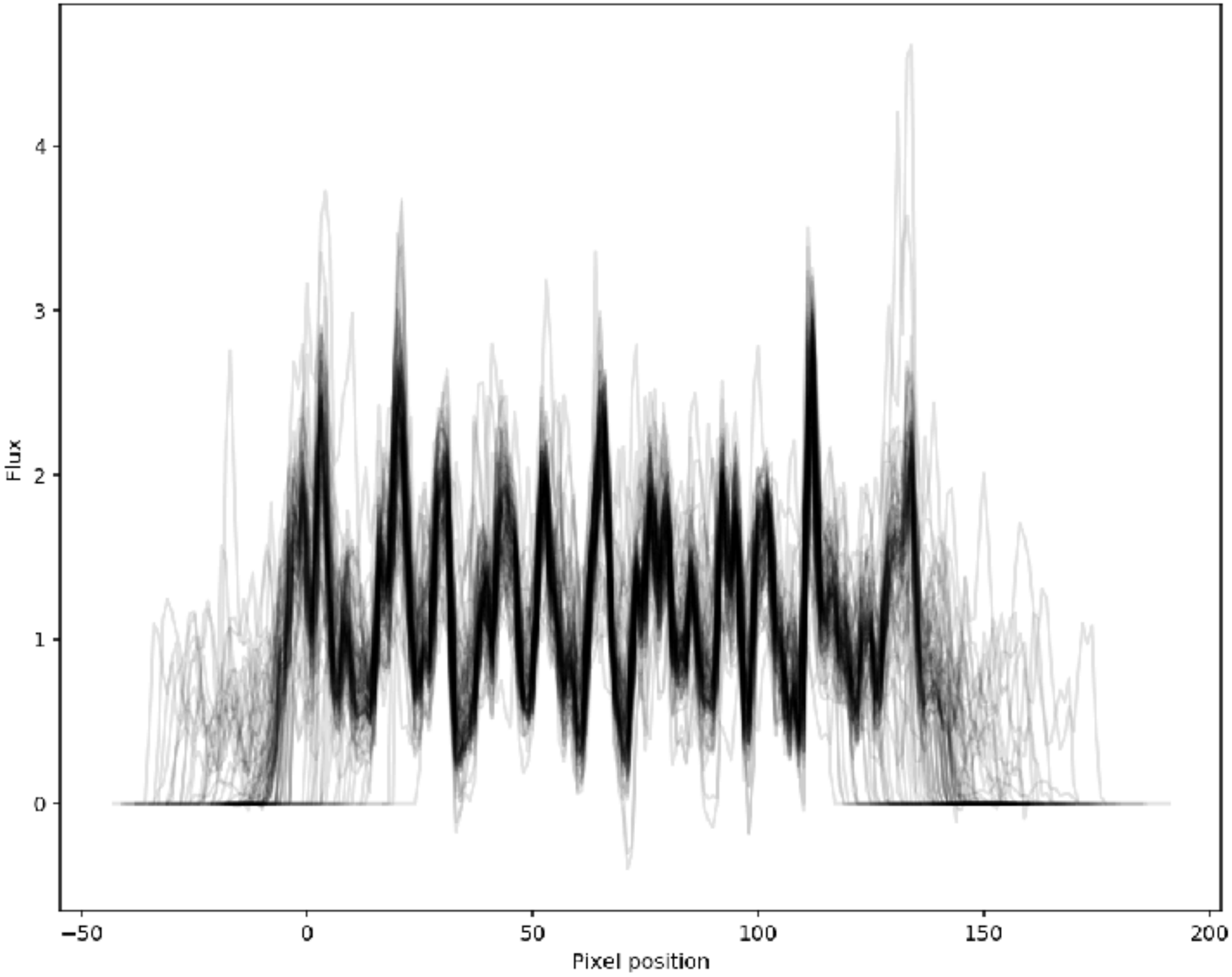
Perform source extraction using the convolution kernel.
Reject saturated and partial trails

Methods



Perform custom aperture photometry on each source.
Many sources overlap with adjacent star trails.

Methods



Register and overplot the star trail line traces.

Channel 41

Channel 53

FFI 1

FFI 2

FFI 3

FFI 4

FFI 5