Are There Any More Planets in the Kepler/K2 Data?

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Adams et al. 2016

Montet et al. 2015

Rizzuto et al. 2017

Livingston et al. 2017

Dressing et al. 2017

Petigura et al. 2017

Pope et al. 2016

Barros et al. 2016

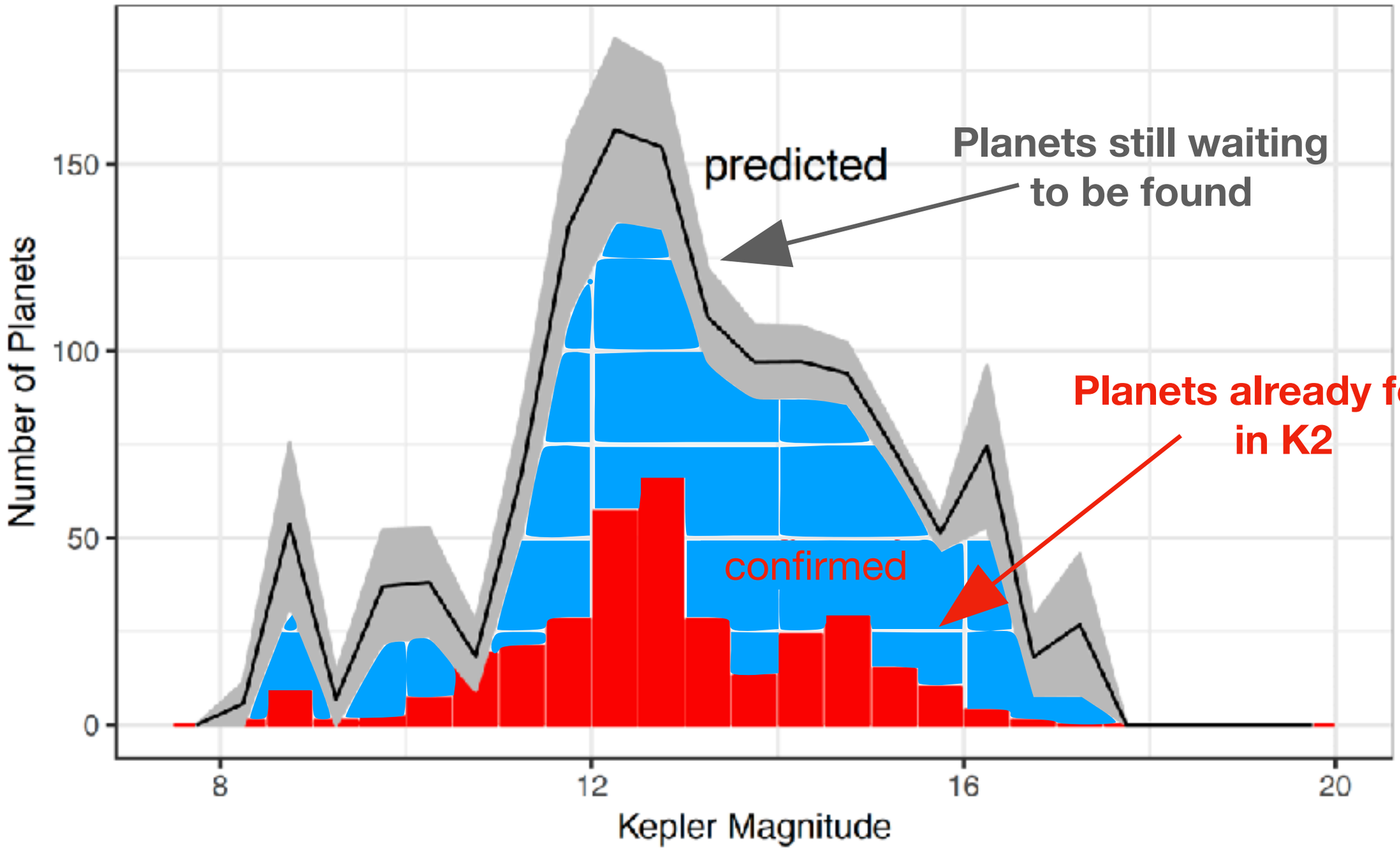
Crossfield et al. 2016

Vanderburg et al. 2016

Yu et al. 2018

Mayo et al. 2018

100's of planets waiting to be found!



Dotson et al 2018

- Improved systematics removal (e.g. K2SFF, EVEREST, K2SC)
- Improved stellar variability removal (e.g. see the `exoplanet` and `celerite` packages)
- Non-Periodic transit hunting methods (to find planets around binaries, planets with strong TTVs)
- Crowded field photometry (to find planets in crowded regions such as the K2C9 Super Stamp)
- Understanding of multi-planet search biases
- Homogenous searches (reapplying our new techniques to early campaigns)

Three New K2 Candidates!

Three Interesting Tales!

K2-43b

First, we can obtain the K2 data using `lightkurve`. In this case, I've written a short script to scrape the HLSPs available for this target, available in the `scripts.py` file. Below I download the data and plot up the two HLSPs.

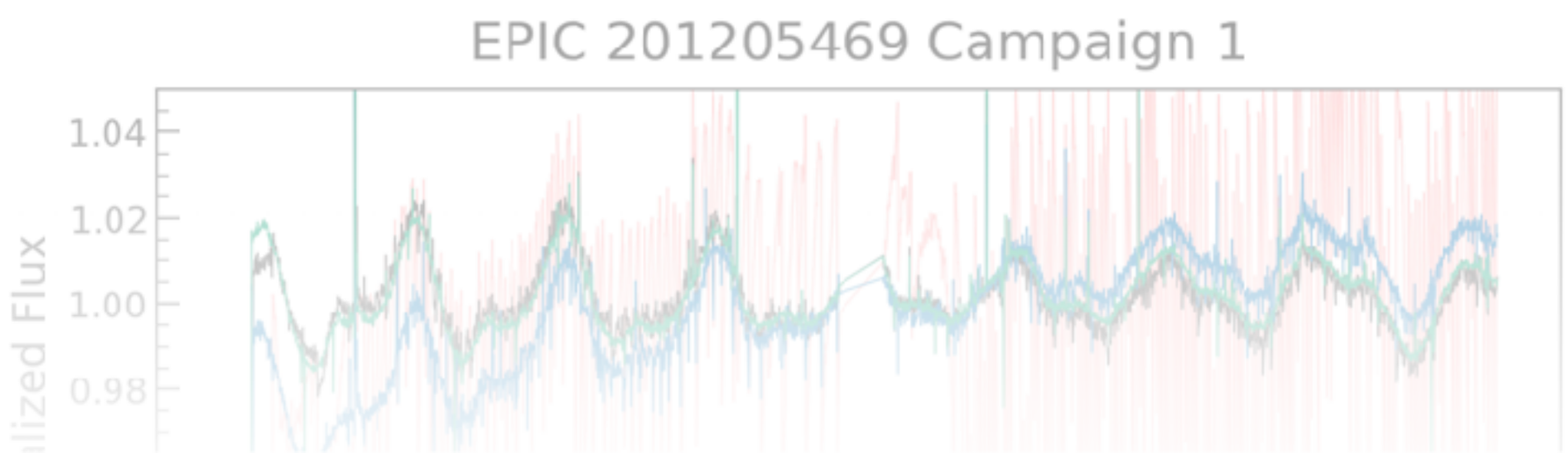
In [2]:
```
import lightkurve as lk
from scripts import fetch_hlsps
import numpy as np
import matplotlib.pyplot as plt
plt.style.use(lk.MPLSTYLE)
```

In [3]:
```
lcf = lk.search_lightcurvefile('EPIC 201205469').download()
```

In [4]:
```
ax = lcf.PDCSAP_FLUX.remove_outliers(10).plot(label='Pipeline Processed')
hlsps = fetch_hlsps(lcf.PDCSAP_FLUX)
for hlsp in hlsps:
    hlsp.remove_outliers(10).plot(ax=ax)
lcf.SAP_FLUX.remove_outliers(10).plot(ax=ax, label='Raw', c='r', alpha=0.3, zorder=-10)

ax.set_ylim(0.9, 1.05)
ax.set_title('EPIC {} Campaign {}'.format(lcf.targetid, lcf.campaign))
```

Out[4]: Text(0.5,1,'EPIC 201205469 Campaign 1')



1. Choice of detrending method can have an impact on your planet yield

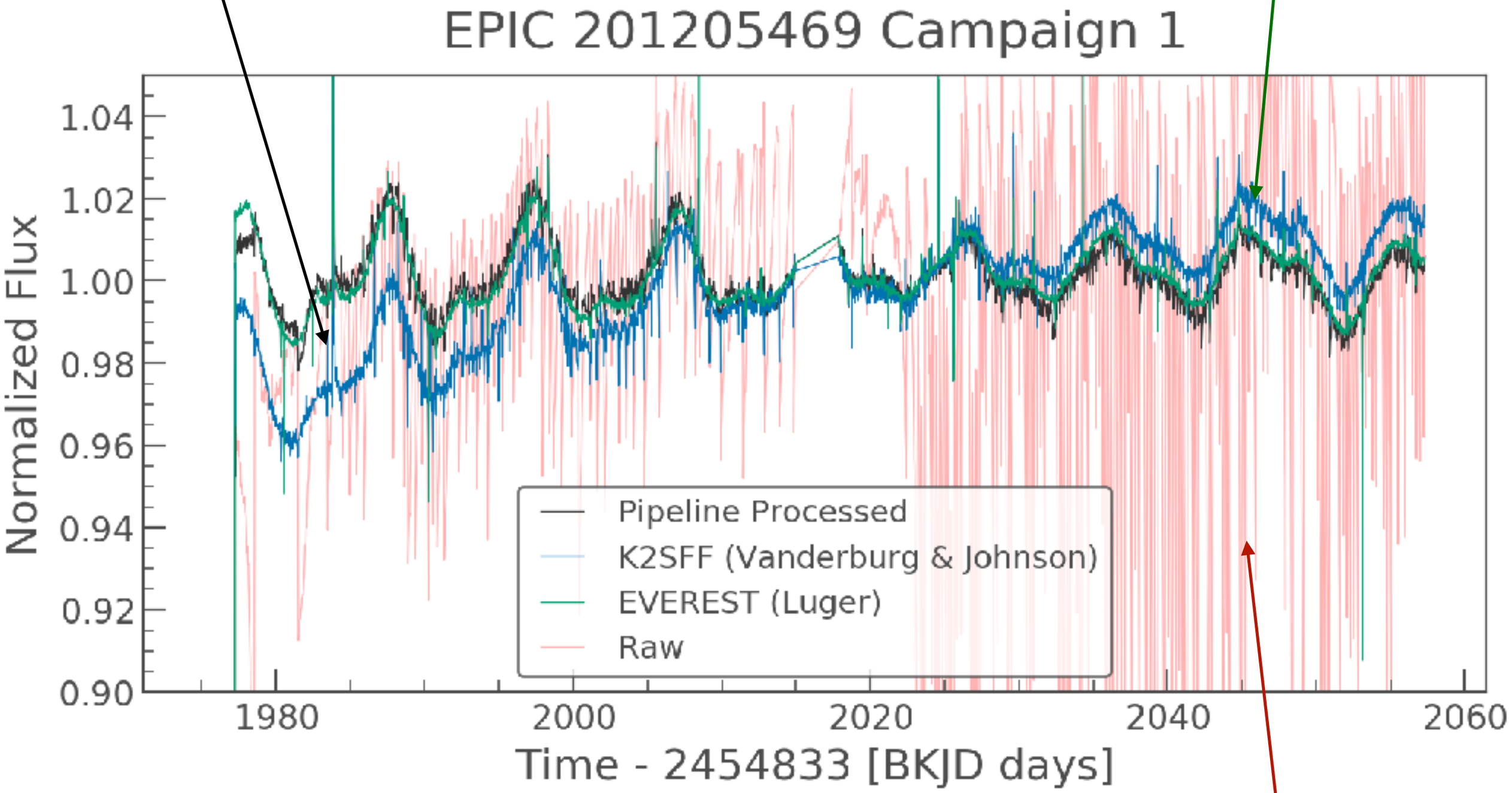
There are three popular detrending methods for K2 data

- Self Flat Fielding (e.g. K2SFF, see Vanderburg and Johnson et al 2015)
- Pixel Level Decorrelation (e.g. EVEREST, see Luger et al 2016, 2018)
- Gaussian Process modeling (e.g. K2SC, see Aigrain et al 2015, 2016)

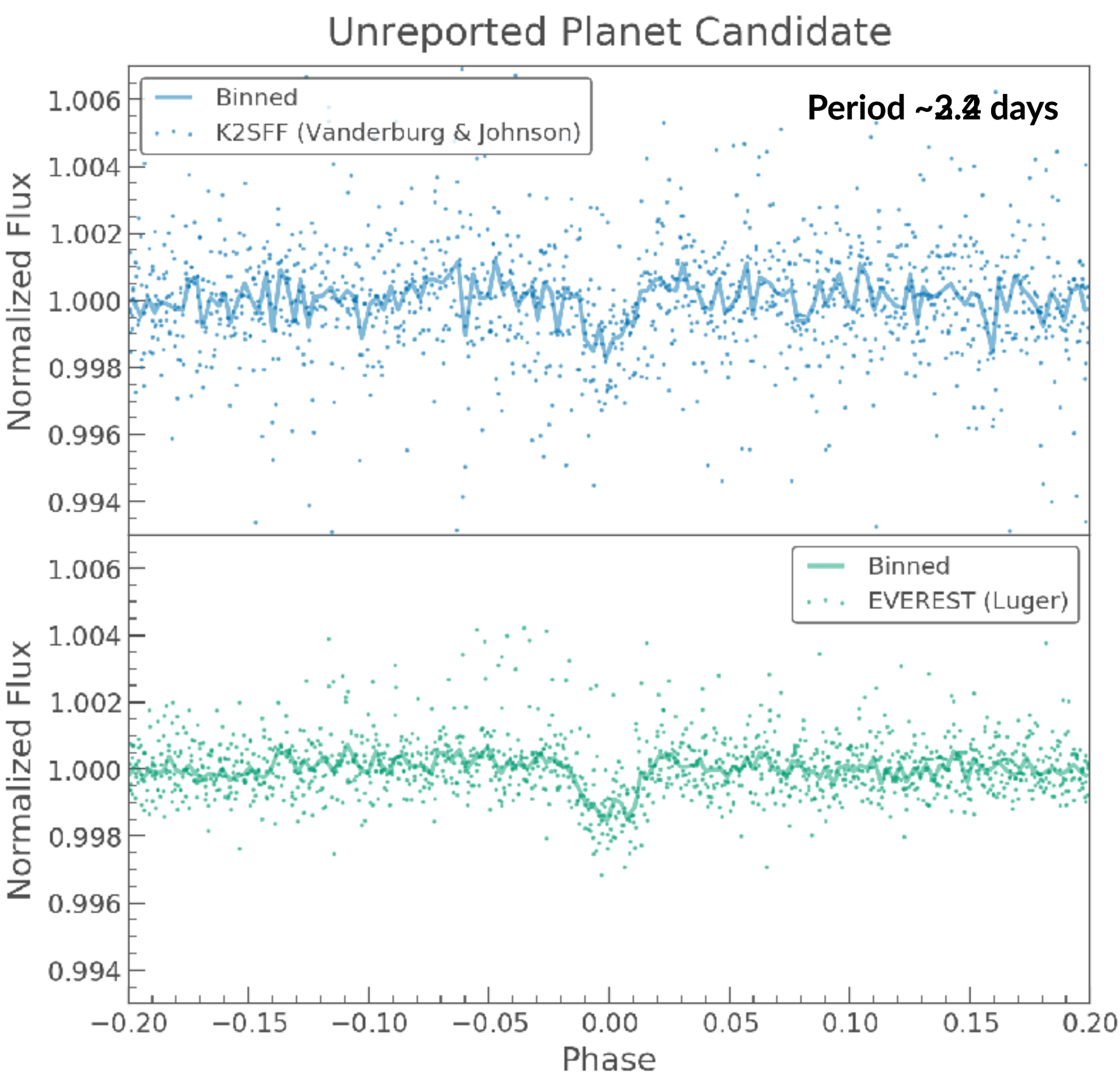
Each of these methods has **strengths** and **weaknesses**

Long term trends vary between detrending methods

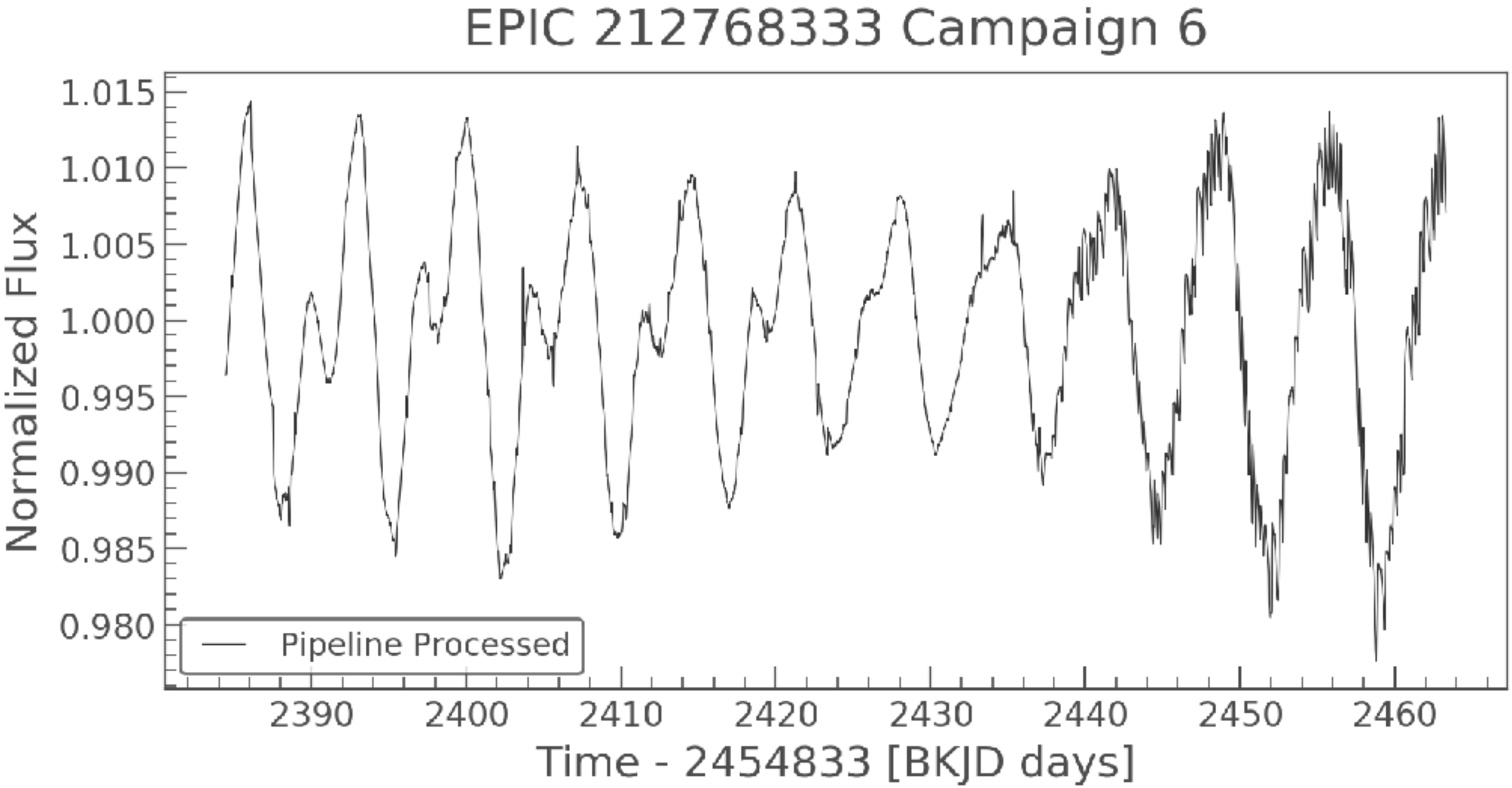
Detrended light curves are less noisy



Raw light curve is noisy

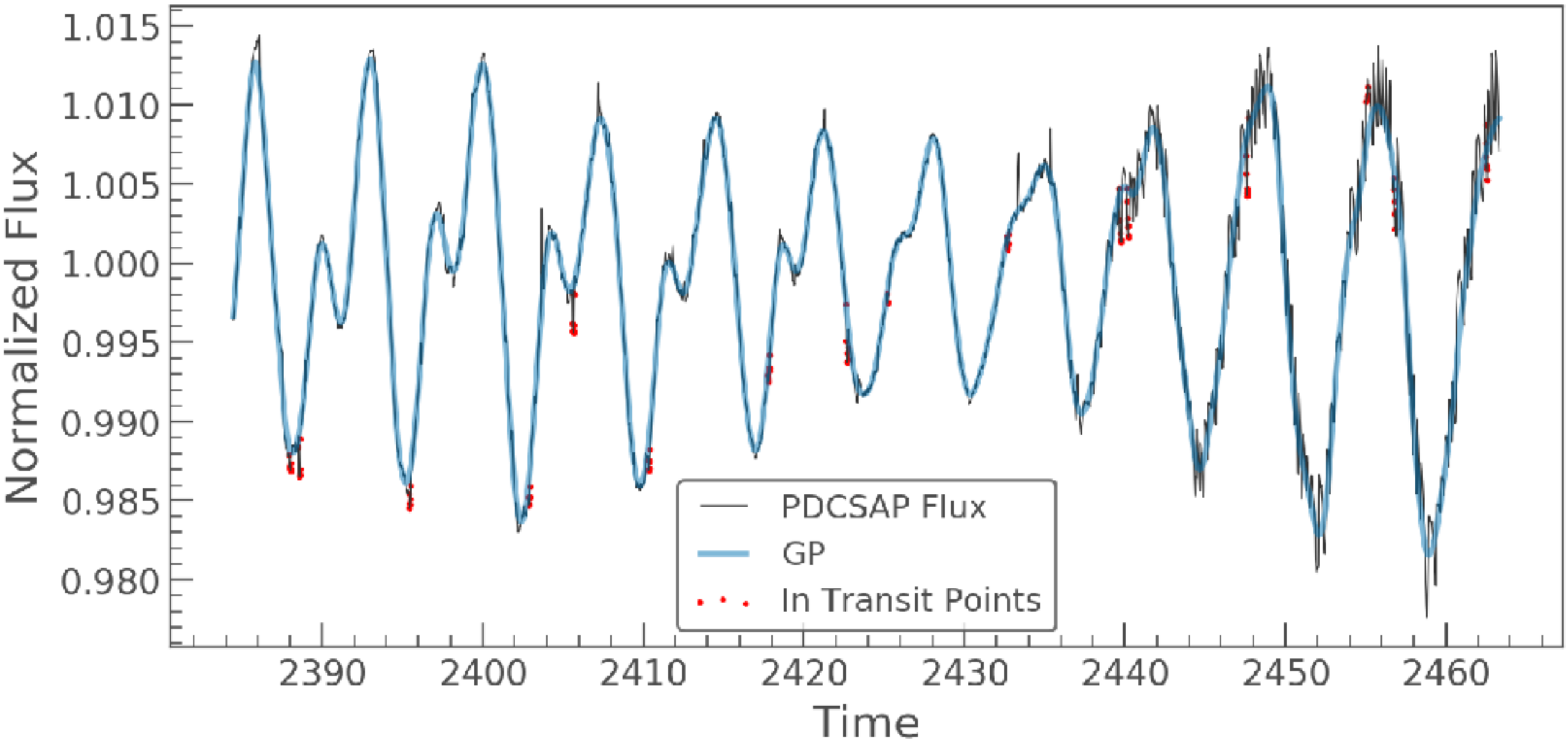

Unreported Planet Candidate
Period ~2.2 days
Binned
K2SFF (Vanderburg & Johnson)
Binned
EVEREST (Luger)
Normalized Flux
1.006
1.004
1.002
1.000
0.998
0.996
0.994
−0.20
−0.15
−0.10
−0.05
0.00
0.05
0.10
0.15
0.20
Phase

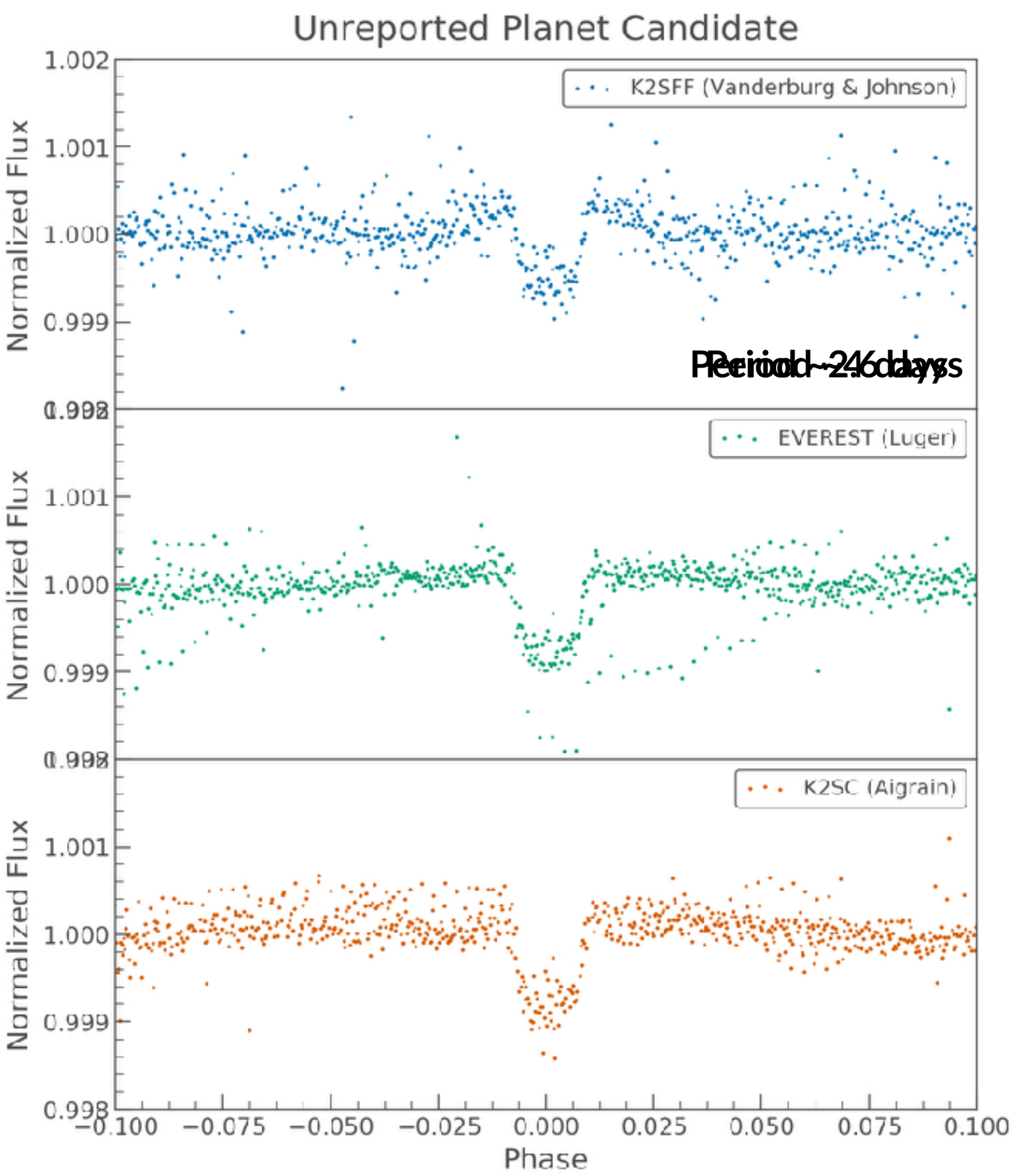
2. Detrending long term stellar variability is important for finding planets


EPIC 212768333 Campaign 6
Normalized Flux
1.015
1.010
1.005
1.000
0.995
0.990
0.985
0.980
Pipeline Processed
2390
2400
2410
2420
2430
2440
2450
2460
Time - 2454833 [BKJD days]

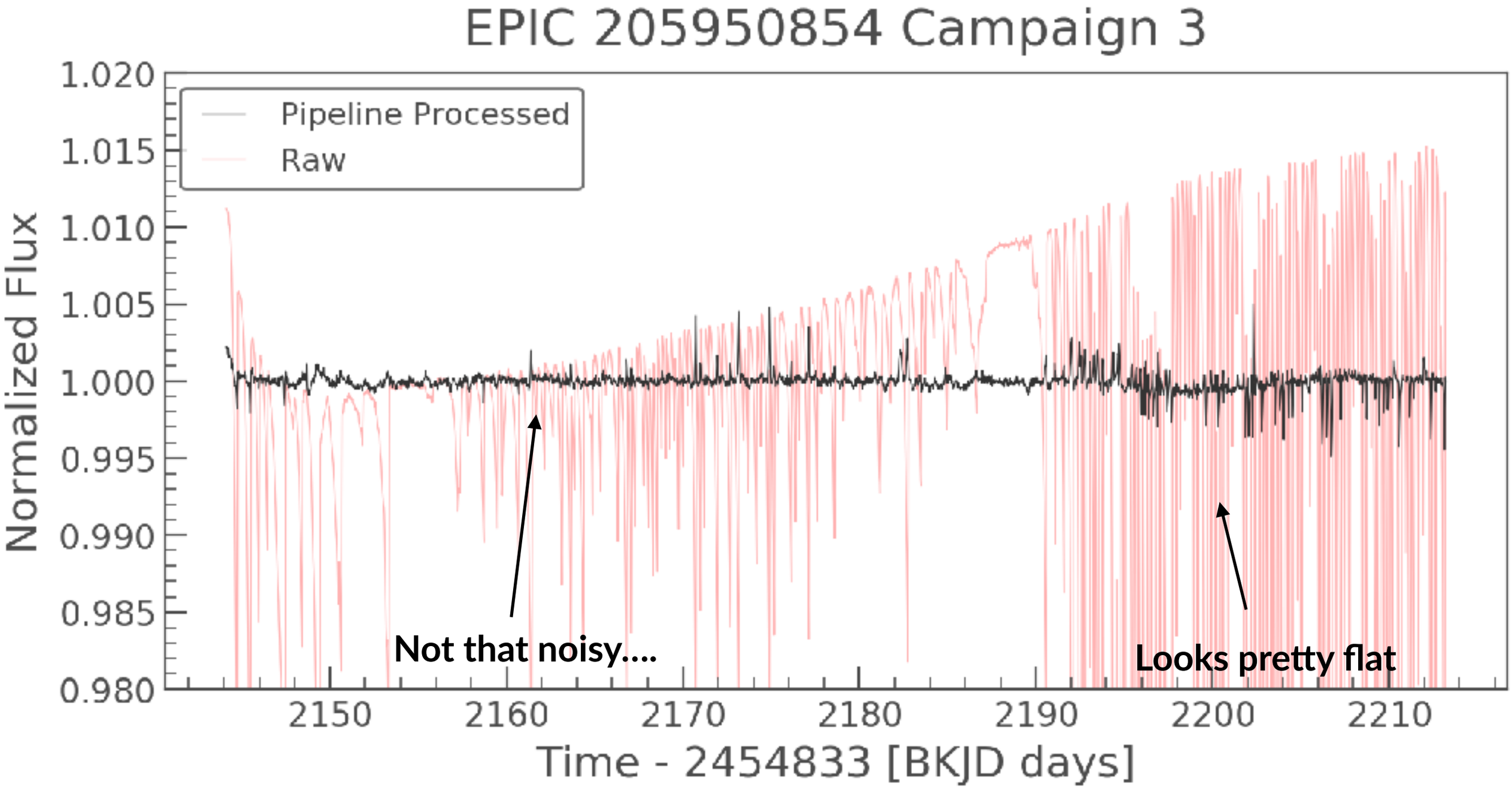
You can remove this long term variability with a Gaussian Process

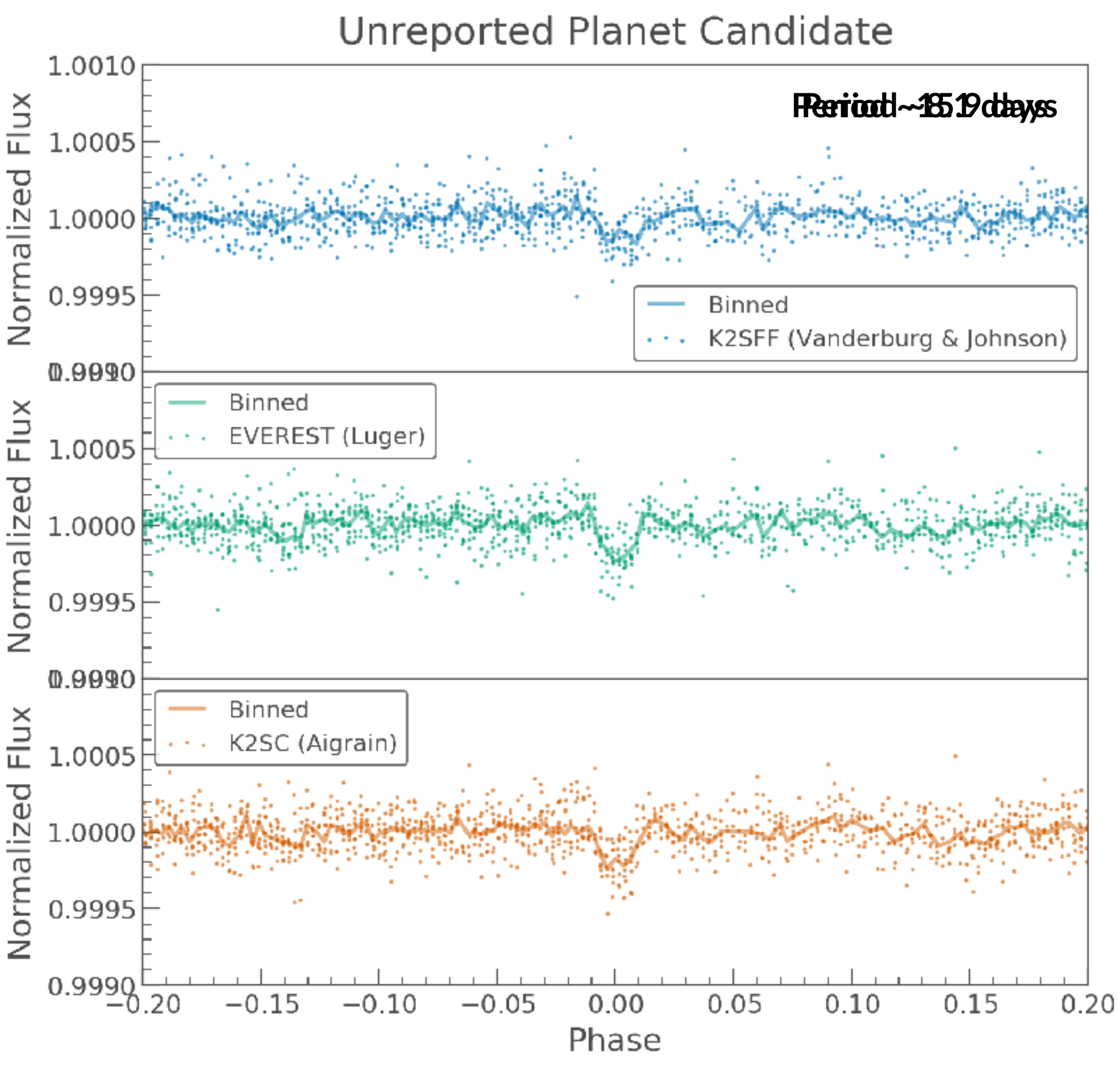
Check out the new `exoplanet` package for help!

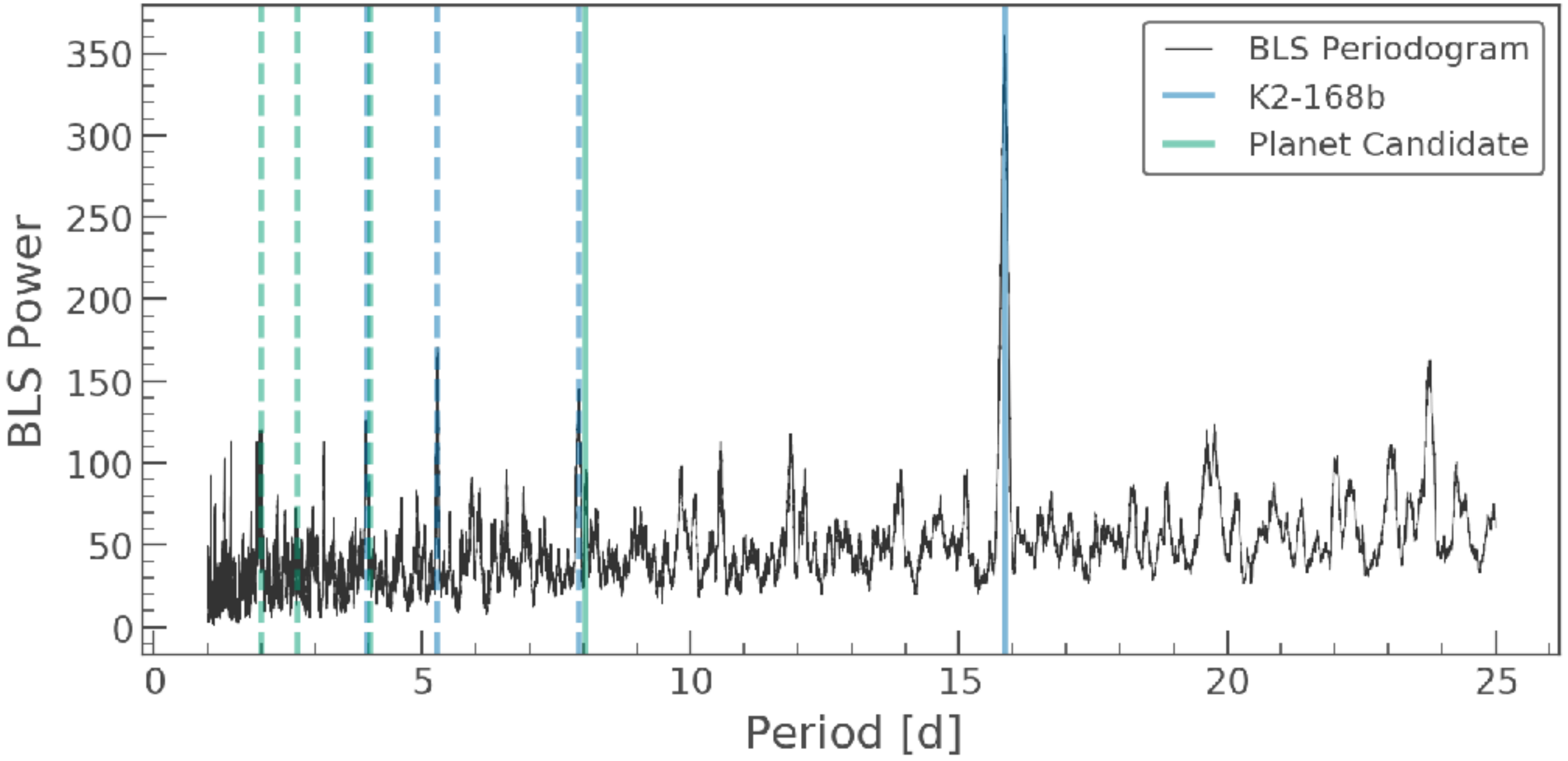

Normalized Flux
1.015
1.010
1.005
1.000
0.995
0.990
0.985
0.980
2390
2400
2410
2420
2430
2440
2450
2460
Time
PDCSAP Flux
GP
In Transit Points

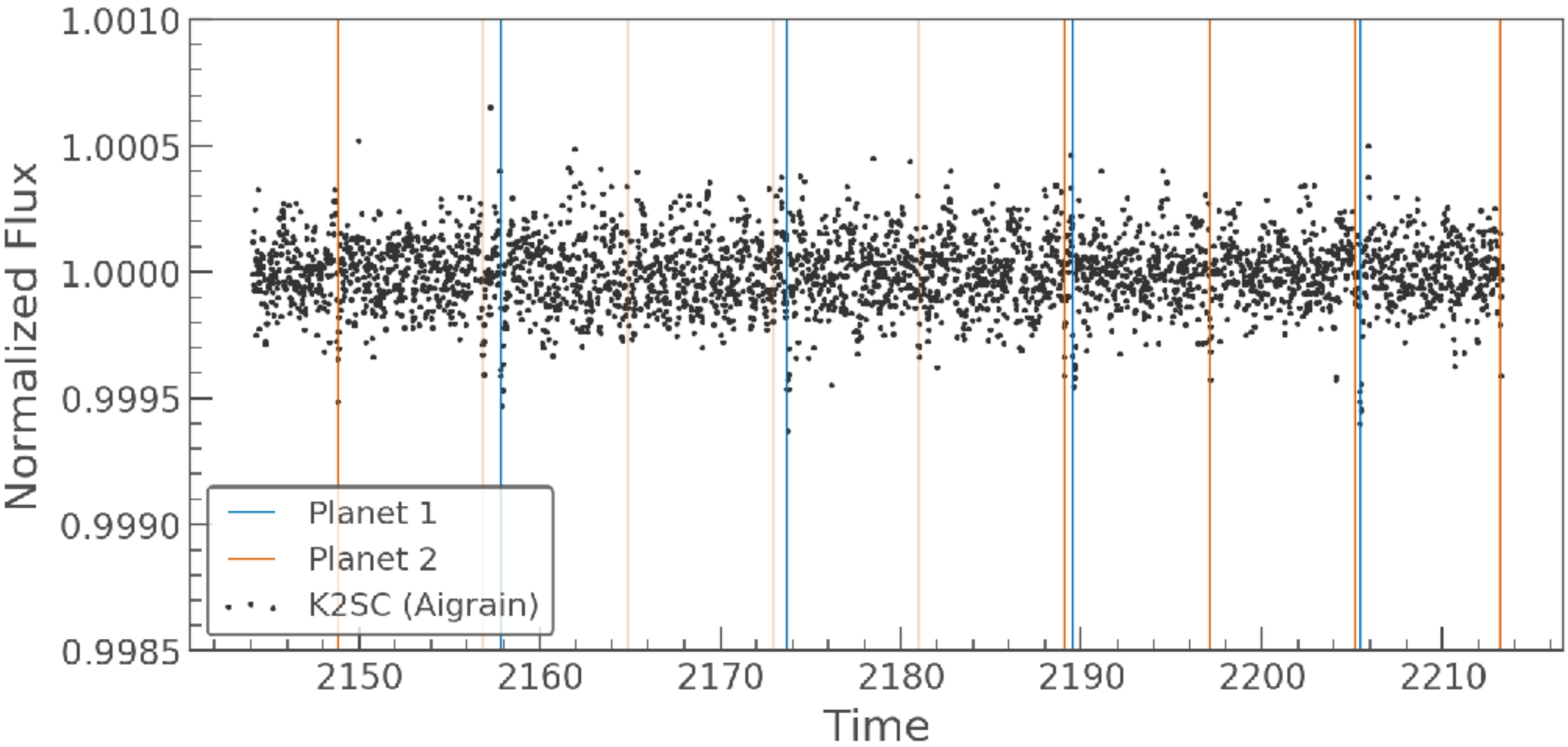

Unreported Planet Candidate
K2SFF (Vanderburg & Johnson)
Normalized Flux
1.002
1.001
1.000
0.999
0.998
Period ~ 2.46 days
EVEREST (Luger)
K2SC (Aigrain)
−0.100
−0.075
−0.050
−0.025
0.000
0.025
0.050
0.075
0.100
Phase

3. Make sure to check near harmonics in your periodogram for hiding planets


EPIC 205950854 Campaign 3
Pipeline Processed
Raw
Normalized Flux
1.020
1.015
1.010
1.005
1.000
0.995
0.990
0.985
0.980
2150
2160
2170
2180
2190
2200
2210
Time - 2454833 [BKJD days]
Not that noisy....
Looks pretty flat


Unreported Planet Candidate
Period ~ 18.19 days
Normalized Flux
1.0010
1.0005
1.0000
0.9995
0.9990
Binned
K2SFF (Vanderburg & Johnson)
Binned
EVEREST (Luger)
Binned
K2SC (Aigrain)
−0.20
−0.15
−0.10
−0.05
0.00
0.05
0.10
0.15
0.20
Phase


BLS Periodogram
K2-168b
Planet Candidate
BLS Power
0
50
100
150
200
250
300
350
0
5
10
15
20
25
Period [d]


1.0010
1.0005
1.0000
0.9995
0.9990
0.9985
Normalized Flux
Planet 1
Planet 2
K2SC (Aigrain)
2150
2160
2170
2180
2190
2200
2210
Time

There are **lots** more planets in the K2 data

- Vary detrending method and parameters to ensure a complete search
- Remove stellar variability carefully
- Check harmonics for hiding resonant planets

Come to our `lightkurve` breakout!