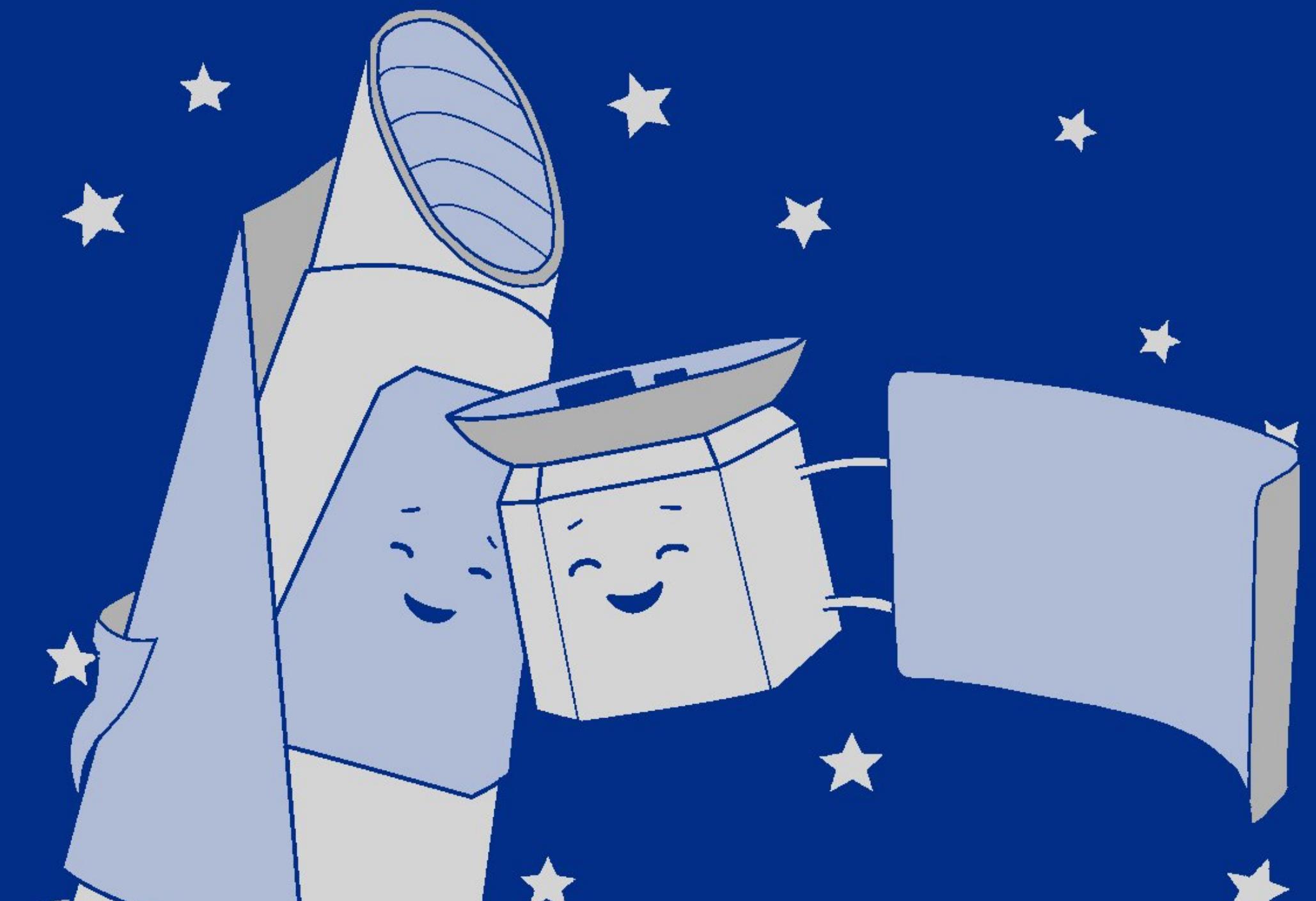
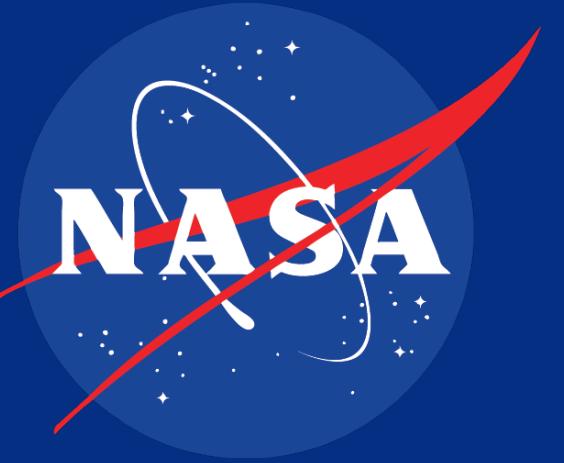


Prospects for Future Discoveries with Kepler and K2



A talk by **Geert Barentsen & the K2 team** at #AAS233,
replacing **Jessie Dotson** (NASA Ames).

Cartoon by Dr. Christina Hedges

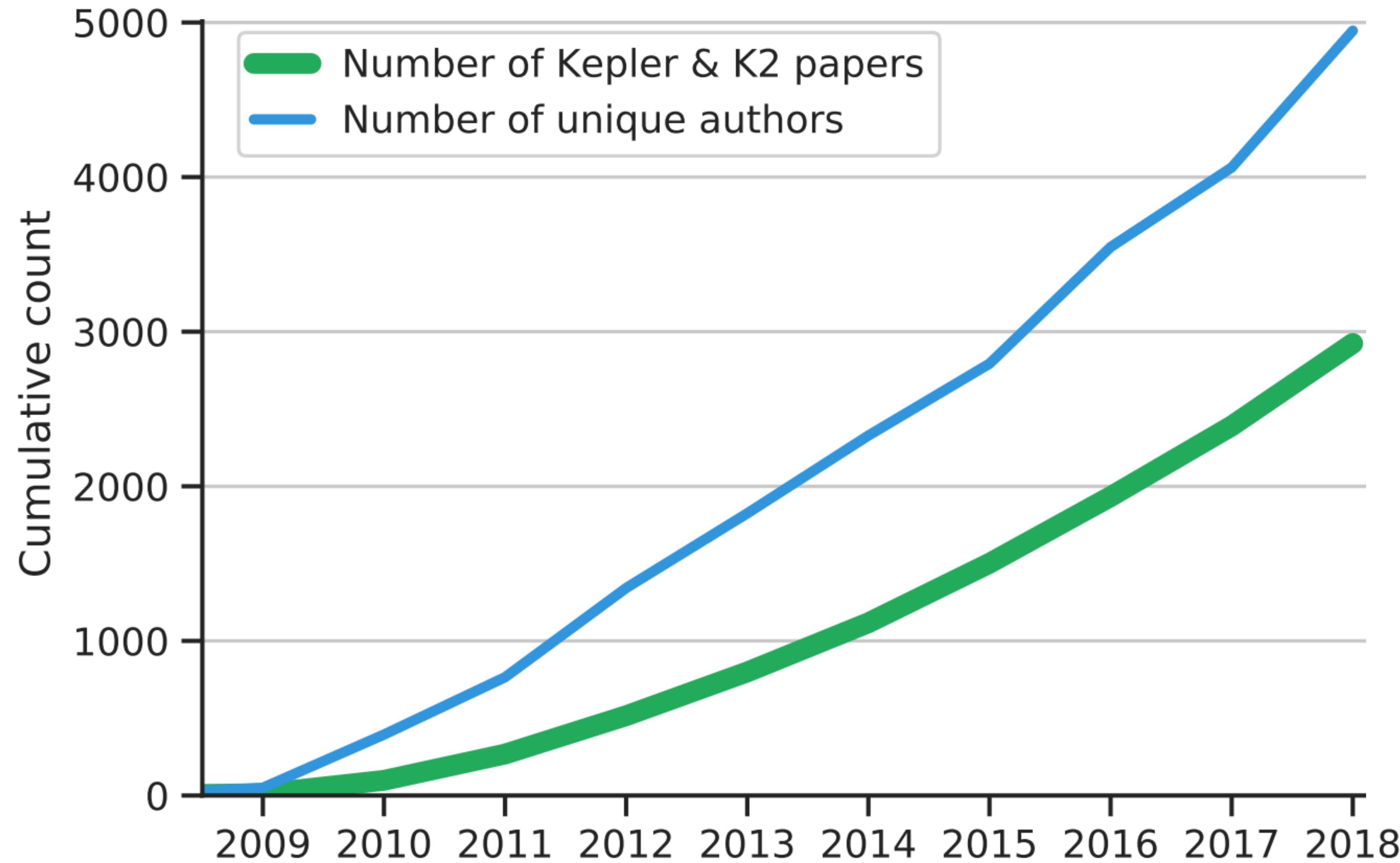


Photo by Marc Schiele on unsplash.com

In 2018, 1.6 publications per day
used Kepler or K2 data

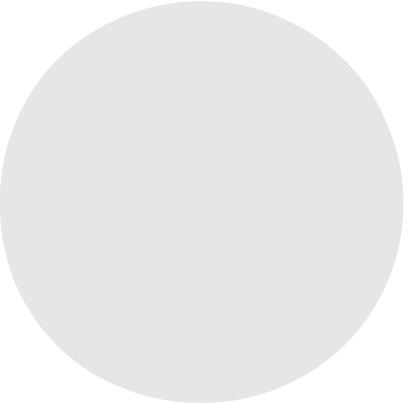
2016: 1.2 per day
2013: 0.8 per day
2010: 0.2 per day

Photo credit: motorverso.com (cc-by)





Will Kepler's discoveries continue?



Is there any science left to do?

Christina Hedges

Are there **any more planets** in the Kepler/K2 data?

Susan Mullally

How can we go about **vetting new planets** from K2?

Daniel Huber

What is left to learn about Kepler/K2 **planet host stars**?

James Davenport

What will Kepler/K2 teach us about **our Galaxy**?

Krista Lynne Smith

What will Kepler/K2 tell us about **other galaxies**?

Daniel Foreman-Mackey

How can new **data analysis methods** get more out of Kepler/K2 data?

Megan Ansdell

How can **machine learning** contribute to mining Kepler data?



Poster session at 1pm today (445.xx)

Nick Saunders (445.02)

Exoplanet science with *Lightkurve*

Michael Gully-Santiago (445.03)

Stellar rotation & asteroseismology with *Lightkurve*

Ken Mighell (445.04)

A tool to improve *Short-Cadence Light Curves*

Steve Bryson (445.05)

Exoplanet Occurrence Rates using Kepler DR25

Jeff Coughlin (445.06)

The *K2 Uniform Reprocessing Effort*

Doug Caldwell (445.07)

The *Kepler Photometer* after 10 years

Jason Curtis (445.08)

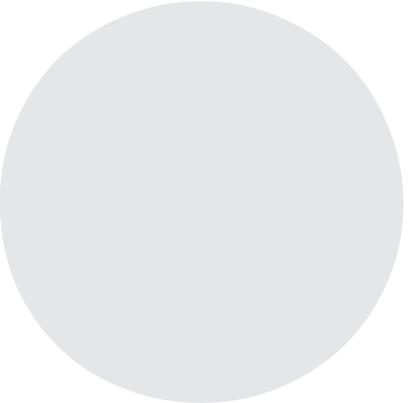
Gyrochronology (Ruprecht 147)

Ellianna Schwab (445.09)

M Dwarfs in the *Kepler Field*



Will Kepler's discoveries continue?



Is there any science left to do?

YES

Kepler's discoveries will continue

- 1) new data
- 2) new methods
- 3) new tools

1. new data

Photo by Samuel Zeller on unsplash.com

GAIA!

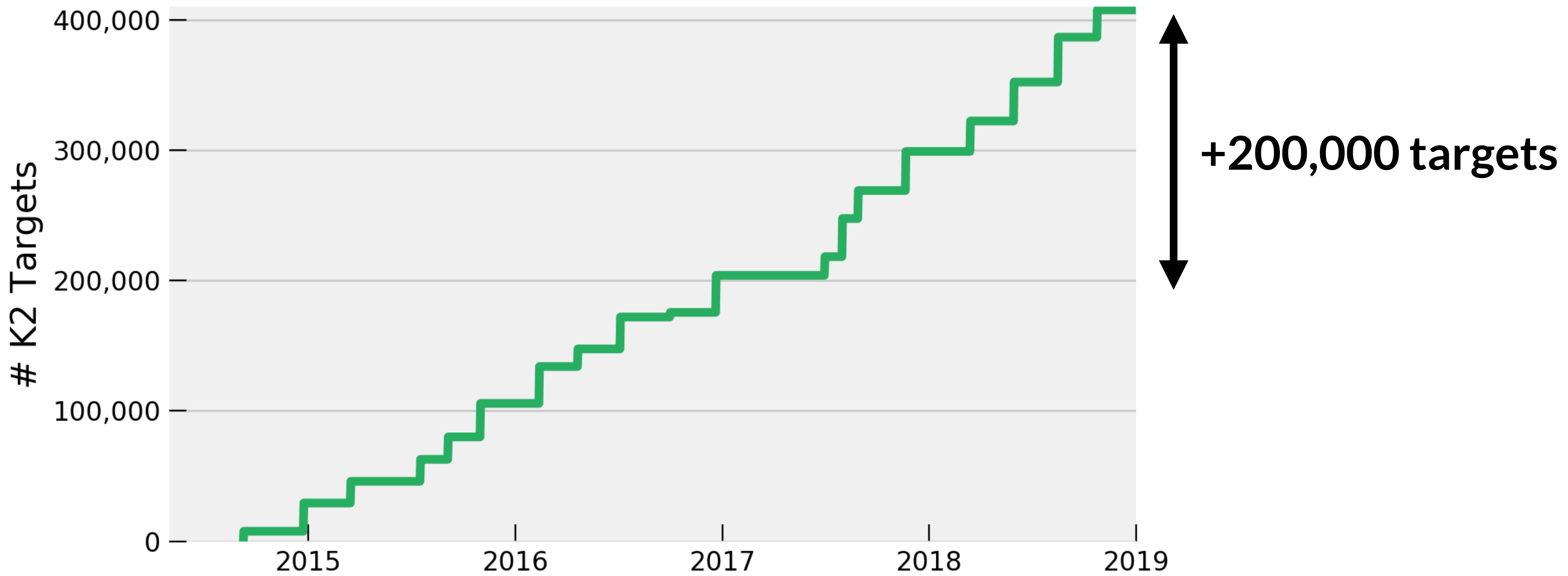


See talks by Huber & Davenport in this session.



Photo by Sebastian Davenport on unsplash.com

The K2 data set doubled in the past 18 months

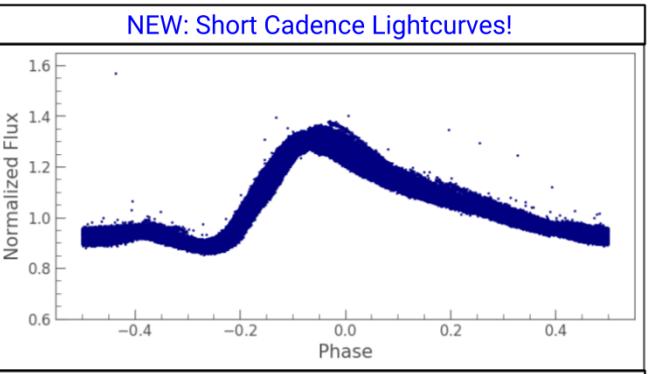


K2 data is being re-processed in a uniform way



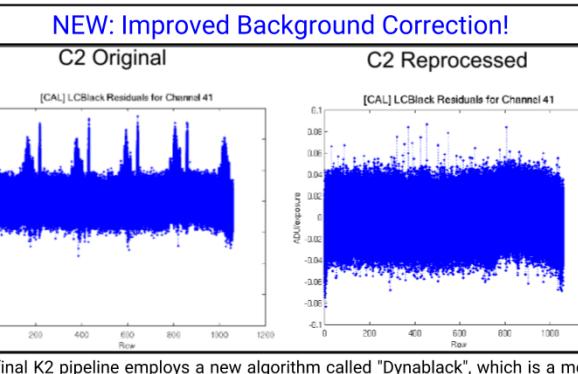
The K2 Mission Global Uniform Reprocessing Effort

Jeffrey Coughlin^{1,2} for the Kepler/K2 Team
¹SETI Institute, ²NASA Ames



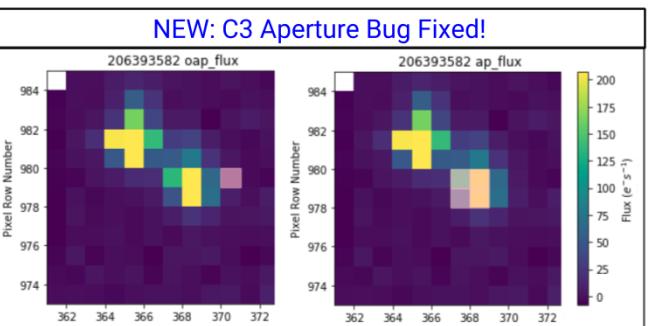
A new feature of the final K2 pipeline is the creation of short-cadence lightcurves. Above is the phased PDC short-cadence lightcurve of an RR Lyr type (pulsating) star, EPIC 206003187, observed in Campaign 3. Cadences right near thruster firings have been removed (see poster 445.04 by Ken Mighell), but no other modifications have been made to this publicly available PDC lightcurve. While not every short-cadence target is guaranteed to be detrended by well by PDC as this one, having these lightcurves available to the community should enable increased science on targets with short-cadence data.

- The Kepler pipeline was quickly adapted to run on K2 data when it was first obtained. Much has been learned about K2 data and many pipeline improvements have been made throughout the past several years.
- Most older campaigns were never reprocessed with newer versions of the K2 pipeline, resulting in campaign-to-campaign variations.
- A global, uniform reprocessing of all K2 data is being conducted to enhance scientific return of the K2 dataset. It is providing for consistent, high-quality data to all community members, and making statistical studies across multiple campaigns more feasible.**
- Campaigns 15 and onward have been processed with the final version of the K2 pipeline. Older campaigns are being reprocessed with the same, final version. Campaigns have been prioritized by the expected enhanced scientific return due to reprocessing.
- This work is being done on a best-effort basis.** There is no guarantee that all campaigns will end up being reprocessed prior to mission closeout, but every campaign that is reprocessed provides better data to the community and enhances scientific return.
- The reprocessed pixel-level data, lightcurves, and auxiliary products can be found at MAST: <https://archive.stsci.edu/k2/> (While old data are accessible, the reprocessed data are the default.)
- The tables below show the status of major and minor pipeline features for each campaign. Check marks indicate that the pipeline feature is present in the currently available data (black for the original data and blue for the reprocessed data). No check mark means that feature is not in currently available data.



The final K2 pipeline employs a new algorithm called "Dynablock", which is a more advanced pixel-level calibration that accounts for time-varying, instrument-induced artifacts in the pixel-level data. Notably, it corrects for CCD crosstalk from the fine guidance sensors, as shown above by the residual black levels as a function of row for the original (left) and reprocessed (right) channel 41 C2 data (note the differing y-axis scales). Dynablock also flags cadences that are suspected to contain rolling band artifacts, which are time-varying electronic signals that can mimic astrophysical signals such as transits, lensing events, and supernovae. This improvement will result in better lightcurves and better identification of lightcurve features due to systematics.

Figure Credit: Doug Caldwell

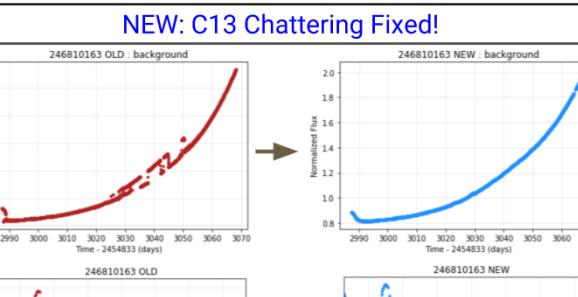


The original C3 processing was affected by a bug that resulted in several thousand targets having poorly chosen photometric apertures. The reprocessing of C3 fixed this bug, as shown by the example above for EPIC 206393582, where the pixels comprising the optimal aperture are identified via a transparent gray overlay. In the original processing (left) the optimal aperture was a single pixel to the right of the target, which is clearly wrong – in the reprocessing (right) the optimal aperture is 4 pixels centered on the target.

		Major Improvements																			
		C0	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19
Improved Background Correction	✓	✓	✓													✓	✓	✓	✓	✓	✓
Better Identification of Bad Spacecraft Pointing	✓	✓	✓													✓	✓	✓	✓	✓	✓
Better Identification of Good Spacecraft Pointing	✓	✓	✓													✓	✓	✓	✓	✓	✓
Improved Cosmic Ray Correction	✓	✓	✓													✓	✓	✓	✓	✓	✓
Short Cadence Lightcurves Produced	✓	✓	✓													✓	✓	✓	✓	✓	✓

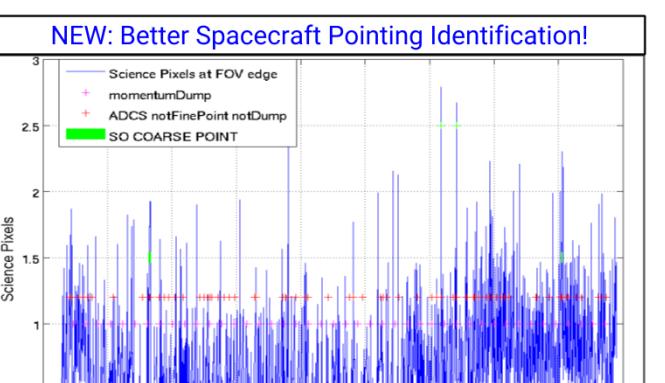
Minor Improvements

	C0	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	
LDE Party Error Flag Ignored	✓	✓	✓													✓	✓	✓	✓	✓	✓
Momentum Dump Flag Used	✓	✓	✓	✓												✓	✓	✓	✓	✓	✓
Smaller Corrected Projected Area	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
FFI Interpolation Bug Fixed	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Screamed Uncertainties Bug Fixed	✓	✓	✓													✓	✓	✓	✓	✓	✓
All Target Files Delivered	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

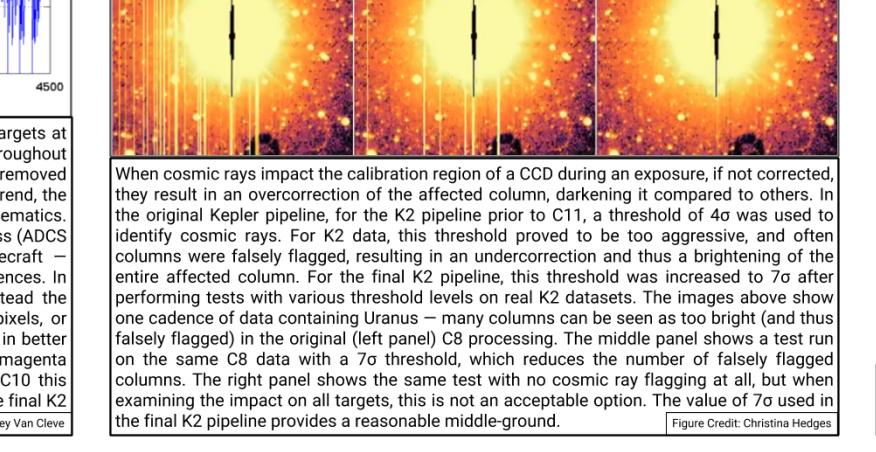


Campaign 13 had a channel (74) corrupted by the very bright star Aldebaran, which caused most of the calibration rows of the CCD to be saturated. As a result, a "chattering" effect was seen in the background and lightcurves of all targets on the channel. The background and lightcurve of the variable star EPIC 246810163 are shown above for the original (left) and reprocessed (right) C13 data. As can be seen, reprocessing was able to better account for Aldebaran and significantly better calibrate the channel.

Figure Credit: Ken Mighell



The above plot (blue line) shows the maximum movement (in pixels) of targets at the edge of the field of view during each long cadence exposure throughout Campaign 15. Outliers due to poor pointing during an exposure should be removed prior to detrending by the PDC module – the less outliers there are to detrend, the more detrending power can be spent on more important large-scale systematics. Previous versions of the K2 pipeline removed outliers marked by a red cross (ADCS notFinePoint notDump), which are automatically flagged by the spacecraft – overzlyzed in some campaigns, resulting in a loss of many good cadences. In the final version of the K2 pipeline, the ADCS flag is ignored, and instead the cadences marked in green (SO Coarse Point) are removed prior to PDC, resulting in better PDC lightcurves and preservation of good cadences. Additionally, the magenta crosses (momentumDump) indicate times of thruster firings – for C6–C10 this flag was ignored, but as these are indeed truly poor quality cadences, in the final K2 pipeline these cadences are also removed prior to PDC.



NEW: Updated Data Release Notes!

K2 Campaign 13

These release notes are for the C13 data currently available at MAST in the nominal K2 data locations, which have been processed with the final version of the K2 pipeline as part of the K2 global uniform reprocessing effort. The original release notes corresponding to the previous version(s) of C13 data can be found in the archived data release notes page.

- At a glance**
- Pointing
 - RA: 72.797116 degrees
 - Dec: 20.787075 degrees
 - Roll: -172.999578 degrees
- Targets
 - 26,242 long cadence (LC) targets
- Clusters and Star Forming Regions

The C13 field of view encompasses part of the Taurus star forming region, including the well-known T Tauri stars HL Tau (EPIC 210490913) and LkCa 15 (EPIC 247520207). The field of view also covers a portion of the Hyades star cluster along with the distant clusters NGC 1647, NGC 1746, and NGC 1817.

Data Quality and Processing Notes

Light Curve Quality

In previous campaigns, the 6-hour spacecraft roll cycle continues to dominate the systematic errors in C13 simple aperture photometry light curves. The pipeline CDPF 12th magnitude noise benchmark is similar to star fields of comparable star density (e.g., C4, C5, C16).

The magnitude dependence of CDPF and its distribution over the focal plane are shown below. Other CDPF benchmarks can be found in the table giving 6-5 for CDPF as a function of magnitude.

Data release notes are updated when a campaign is reprocessed, with an effort made to standardize them across all campaigns. Old versions of the notes, corresponding to the old data, are preserved and still accessible.

See poster by Jeff Coughlin at 1-2pm today (445.06)

2. new methods

Examples include ...

Gaussian Processes

Gradient-based methods

Machine Learning

See talks by Foreman-Mackey & Ansdell in this session.

3. new tools

Photo by Todd Quackenbush on unsplash.com

[!\[\]\(481c10b2aee2772ec45f83f261a0a974_img.jpg\) lightkurve](#)

1.0b9

[Search docs](#)

GETTING STARTED

- [Quickstart](#)
- [Installation](#)
- [API documentation](#)

TUTORIALS

- [Introduction to lightkurve](#)
- [Science with lightkurve](#)
- [Systematics correction using lightkurve](#)

ABOUT LIGHTKURVE

- [Contributing and reporting issues](#)
- [Citing and acknowledging lightkurve](#)
- [Other software](#)

Docs » Welcome to lightkurve!

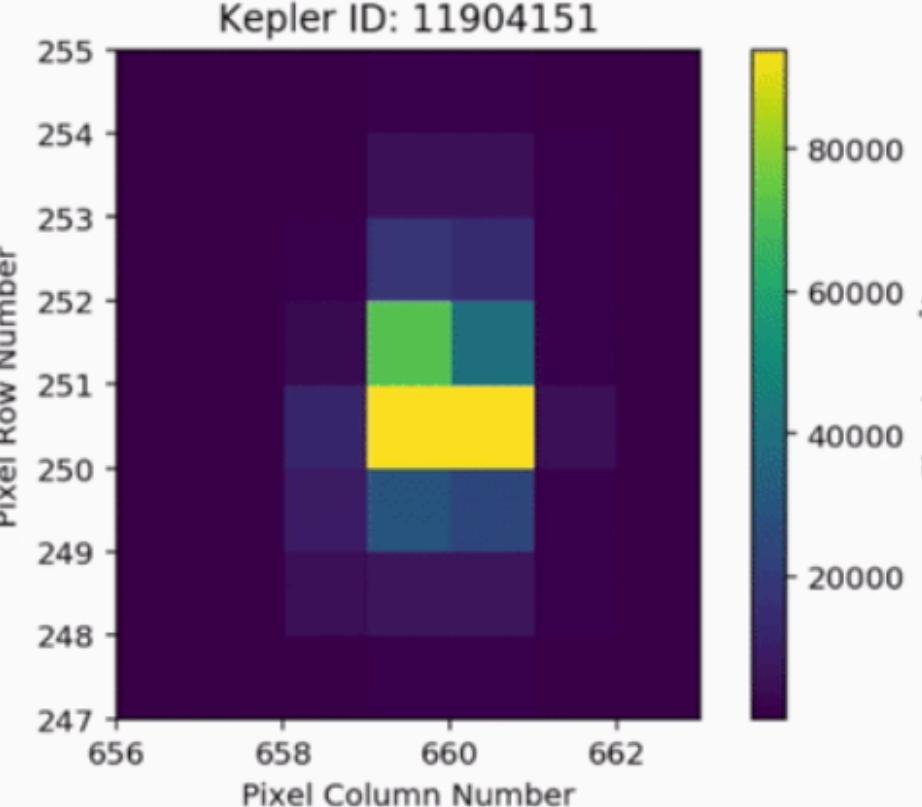
[View page source](#)

Welcome to lightkurve!

The **lightkurve** Python package offers a beautiful and user-friendly way to analyze astronomical flux time series data, in particular the pixels and lightcurves obtained by **NASA's Kepler, K2, and TESS missions**.

```
%%capture
tpf = KeplerTargetPixelFile.from_archive('kepler-10', quarter=5)

tpf.to_lightcurve().plot();
```



Kepler ID: 11904151

Pixel Row Number

Pixel Column Number

Flux ($e^{-} s^{-1}$)

This package aims to lower the barrier for both students, astronomers, and citizen scientists interested in analyzing Kepler and TESS space telescope data. It does this by providing high-quality

The screenshot shows the official documentation for the `lightkurve` Python package. The top navigation bar includes the `lightkurve` logo, version `1.0b9`, and a search bar labeled "Search docs". The left sidebar contains sections for "GETTING STARTED" (Quickstart, Installation, API documentation), "TUTORIALS" (Introduction to lightkurve, Science with lightkurve, Systematics correction using lightkurve), and "ABOUT LIGHTKURVE" (Contributing and reporting issues). The main content area on the right is titled "Tutorials" and lists several topics:

- Introduction to lightkurve
 - What are Target Pixel File objects?
 - What are Light Curve objects?
 - What are Light Curve File objects?
 - Interactively inspecting Target Pixel Files and Lightcurves
- Science with lightkurve
 - How to recover a known planet in Kepler data
 - How to combine lightcurves from different Kepler quarters
 - How to perform aperture photometry with custom apertures
 - How to cut out Target Pixel Files from Kepler Super Stamps or TESS FFIs
 - How to store a light curve in FITS format?
- Systematics correction using lightkurve
 - How to remove common systematics using basis vectors (CBVs)
 - How to remove K2 motion systematics with SFF
 - How does the SFF method work?
 - Replicating Vanderburg & Johnson 2014 using lightkurve
 - How to identify time-variable background noise (“rolling bands”)?

[Search docs](#)

CONTENTS:

- [Simulate Target](#)
- [Scope Math](#)
- [Batch](#)
- [Source Code on Github](#)
- [Examples](#)

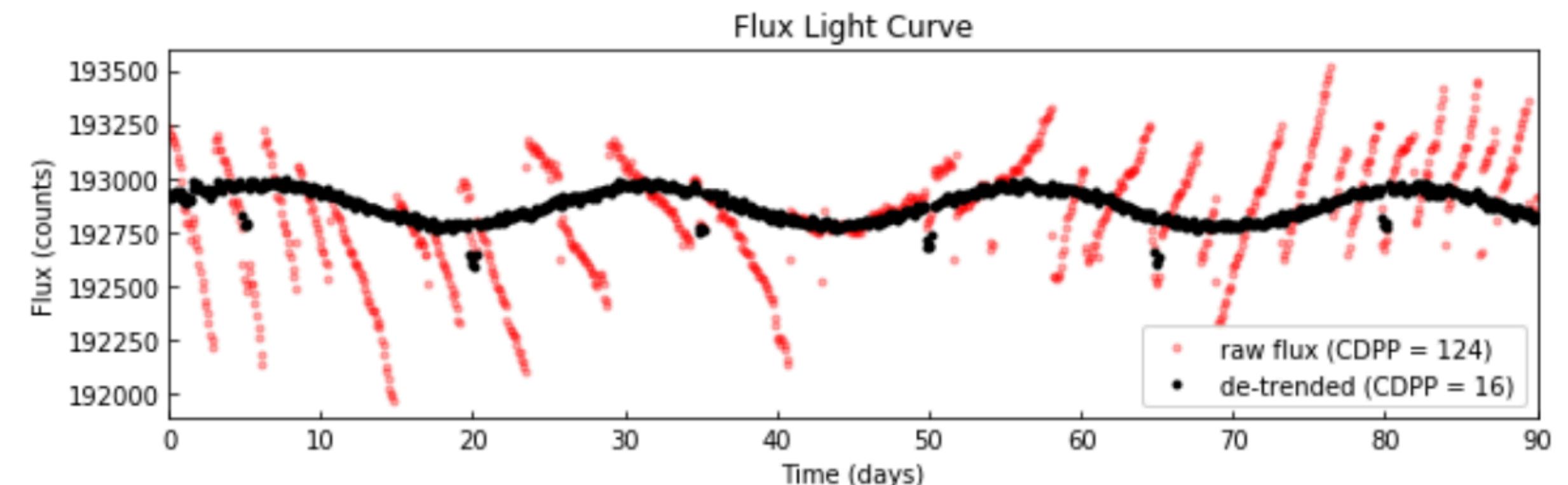
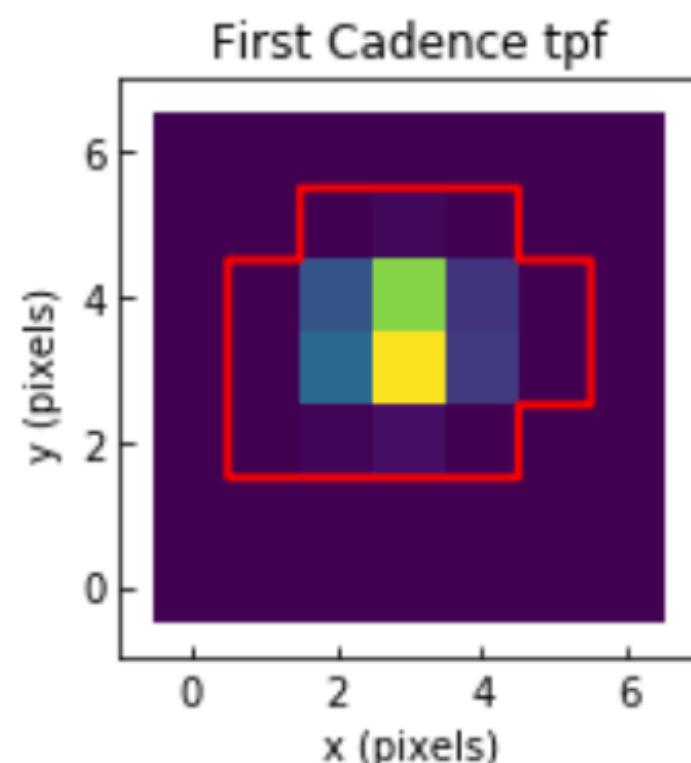
scope

Welcome to scope!

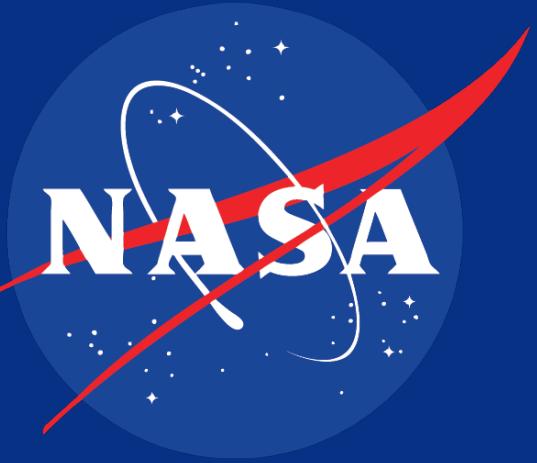
Simulated CCD Observations for Photometric Experimentation

scope
and s
creat

```
In [6]: target.add_variability().plot()
```

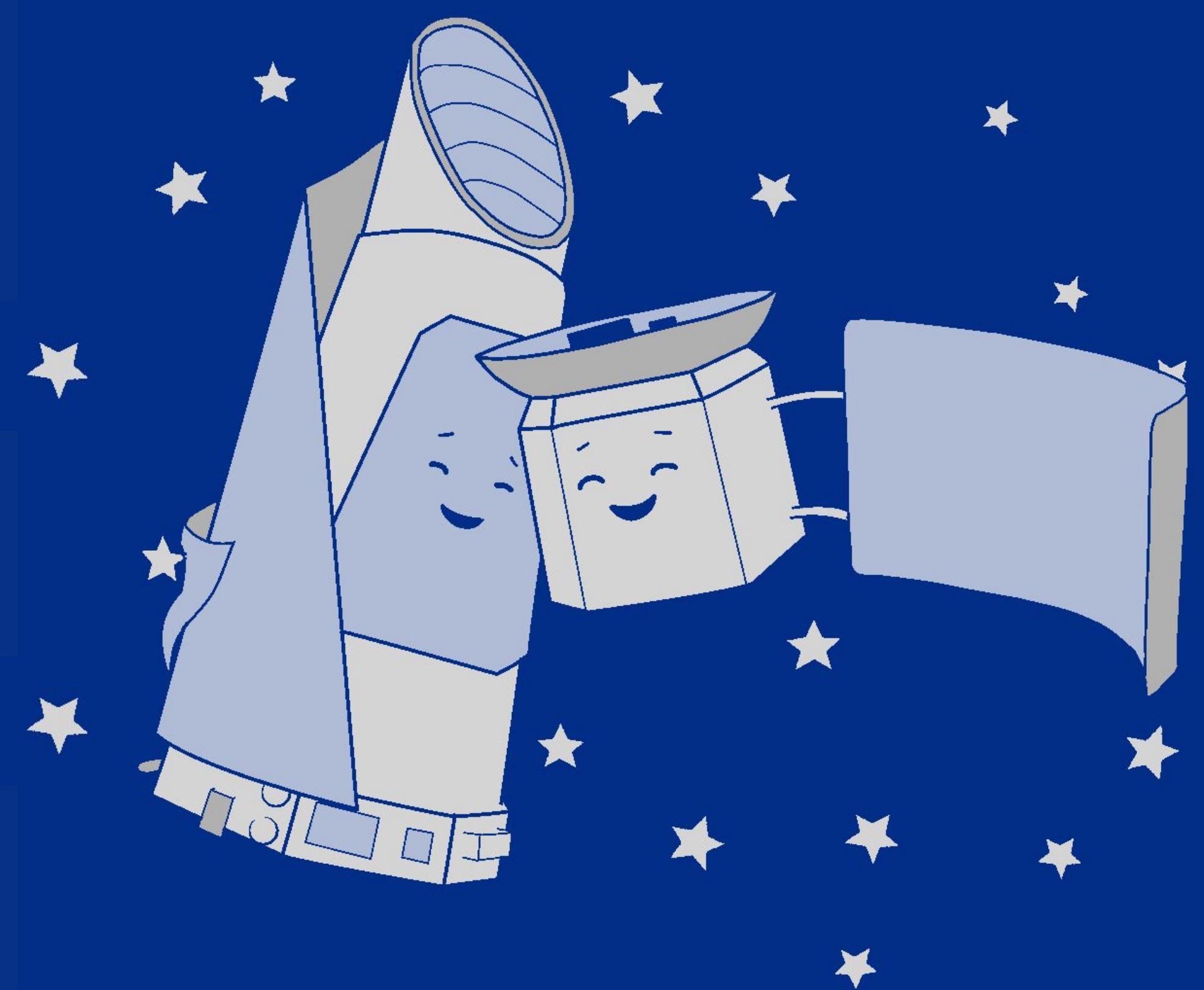


<https://nksaunders.github.io/scope>



While Kepler's data collection has ended,
the space photometry revolution
is only just getting started!

Congratulations to TESS for
a beautiful first data release!



Cartoon by Christina Hedges

KEPLER&K2

SciConV:

10 years since launch

2019

March 4 – 8, 2019
Glendale, CA

Late posters accepted through Jan 15!

