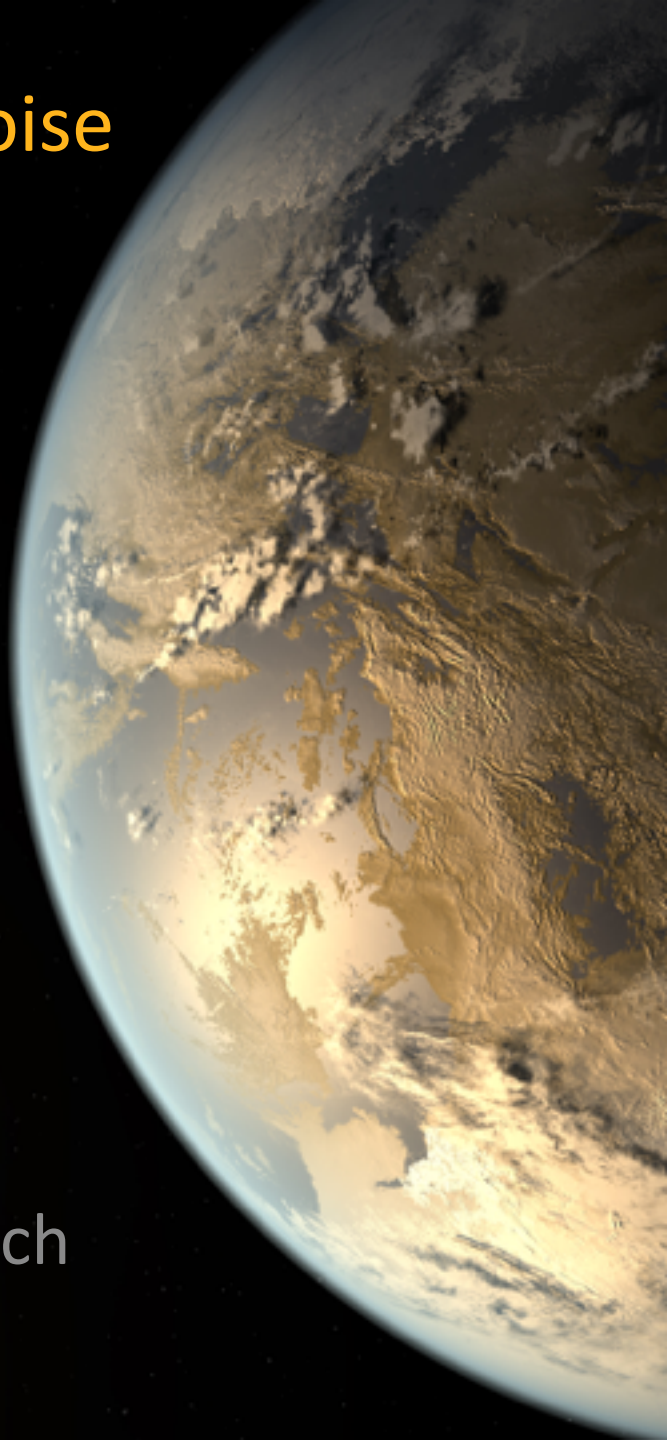
Astrophysical and Instrumental Noise Sources: Transits

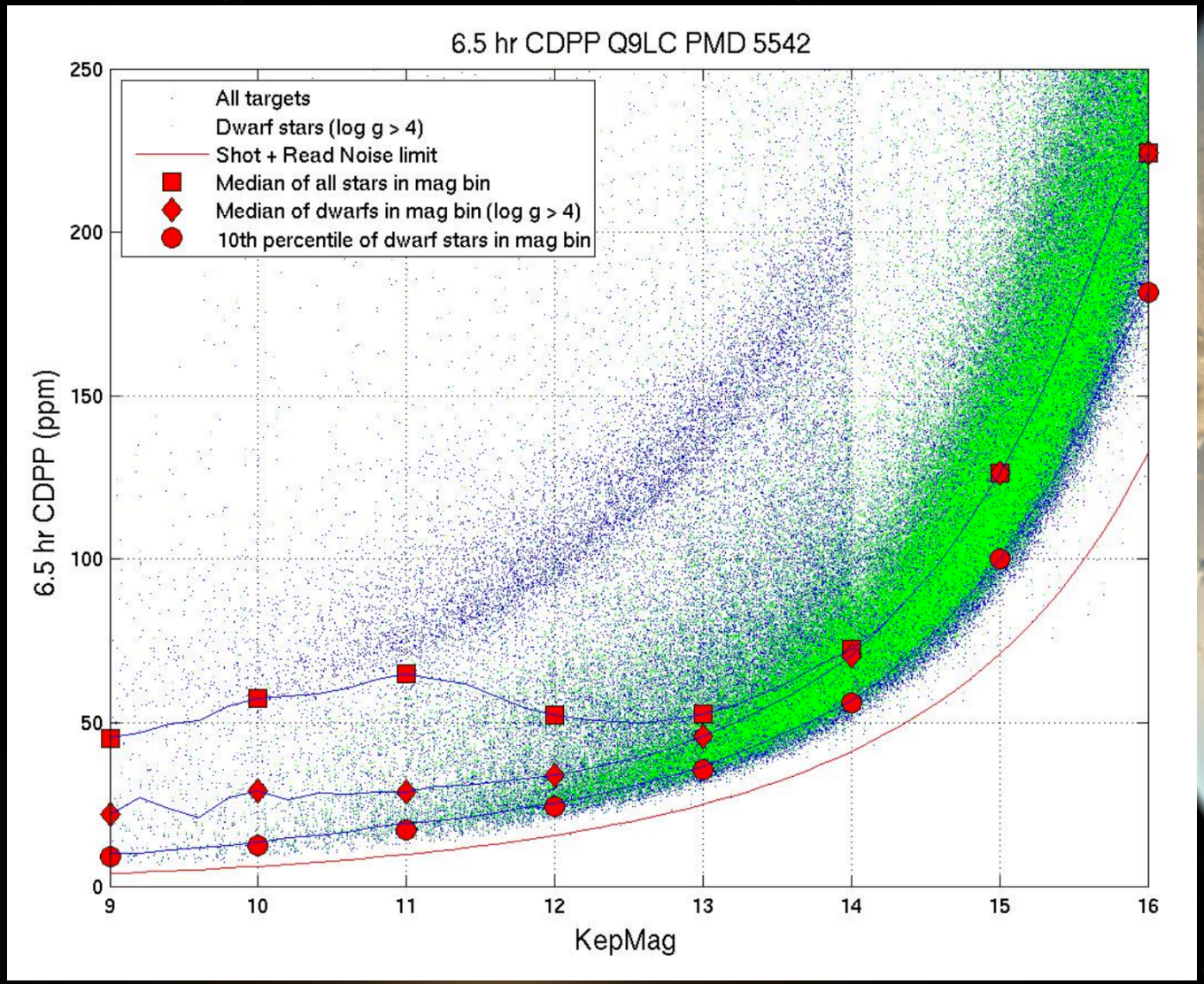
Sagan Workshop – July 19 2016



Jessie Christiansen

NASA Exoplanet Science Institute/Caltech

Why do we care about noise?



Christiansen+2013

Overview

Spacecraft do stuff!

Stars do stuff!

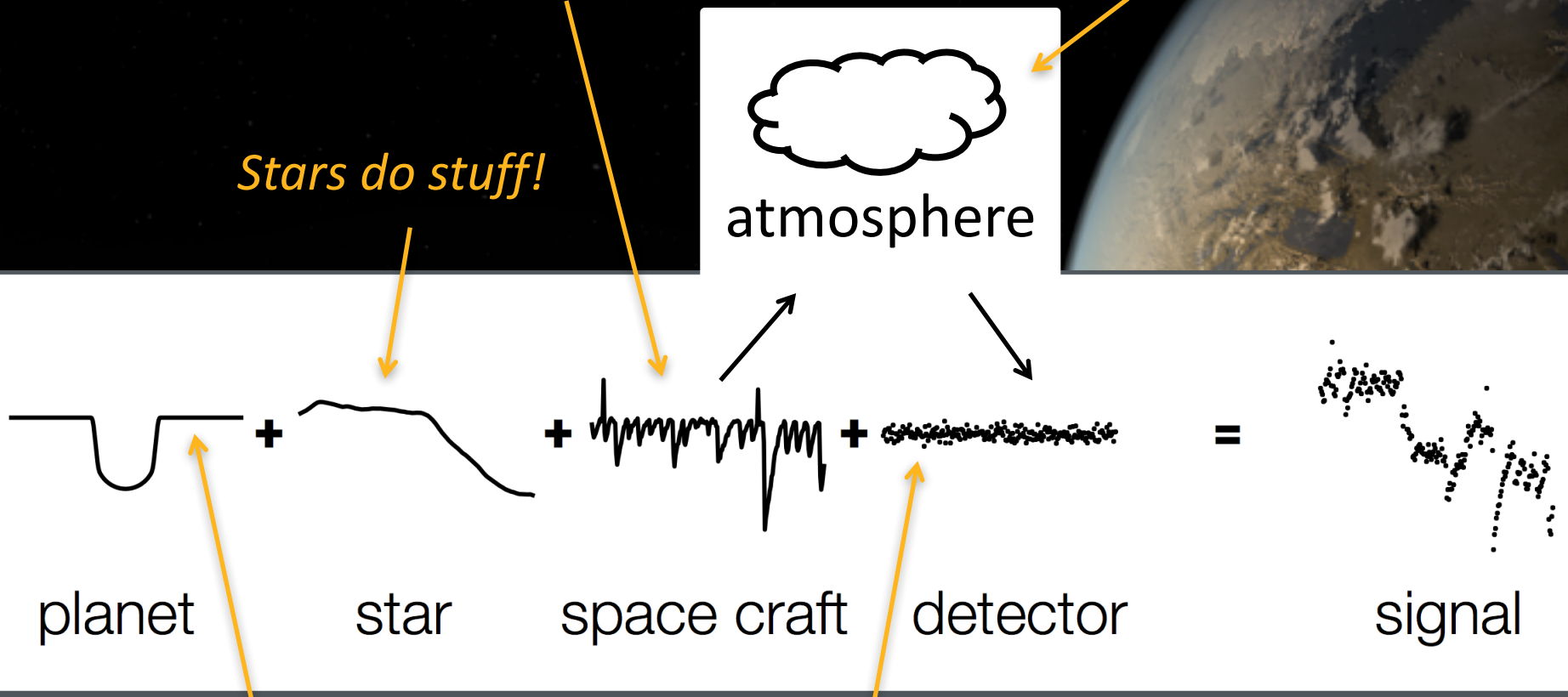
Credit: Dan Foreman-Mackay, Davos

Overview

Telescopes do stuff!

Atmospheres do stuff!

Stars do stuff!



(Planets do stuff, too!)

Detectors do stuff!

Credit: Dan Foreman-Mackay, Davos

Stars do stuff…

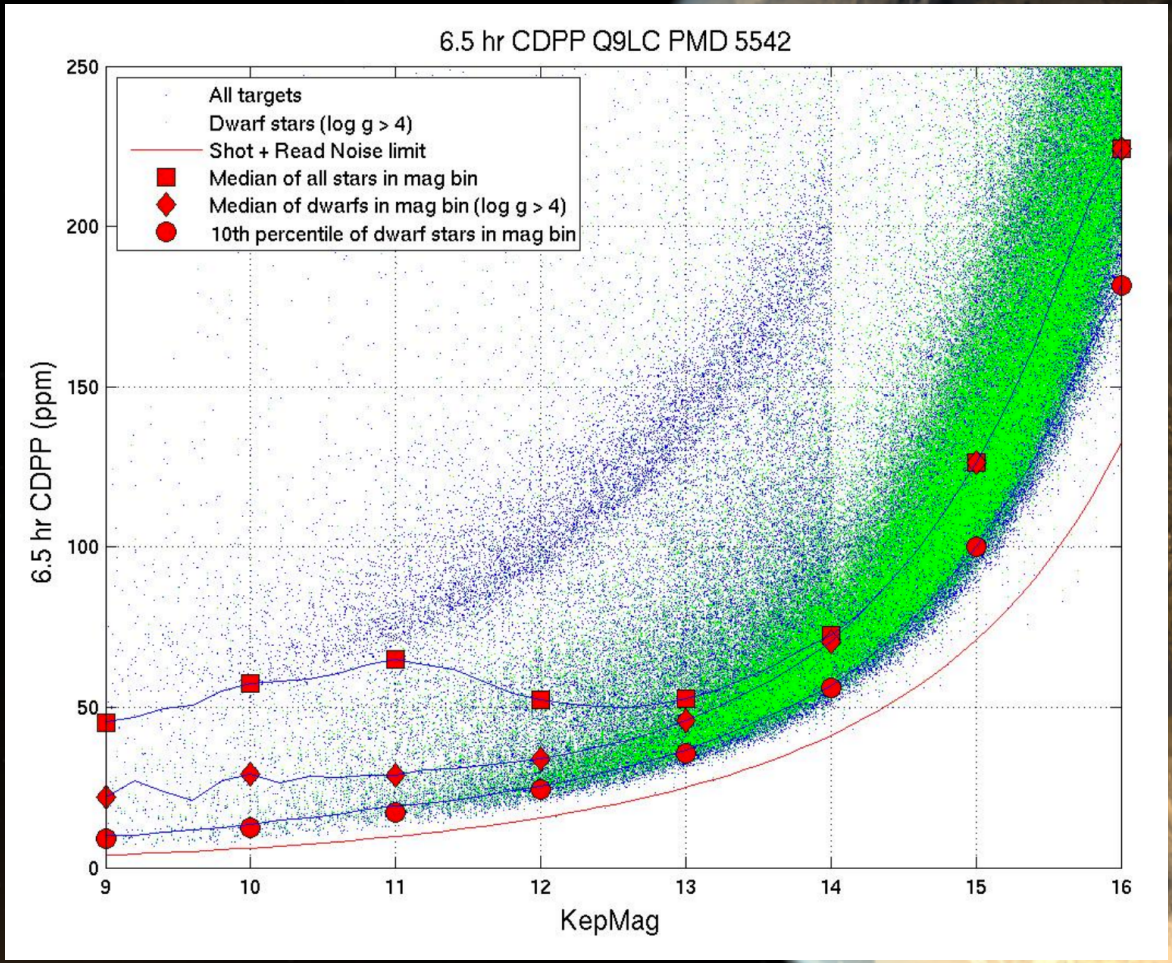
They emit photons!

Poisson noise: $\sigma = \sqrt{\lambda}$

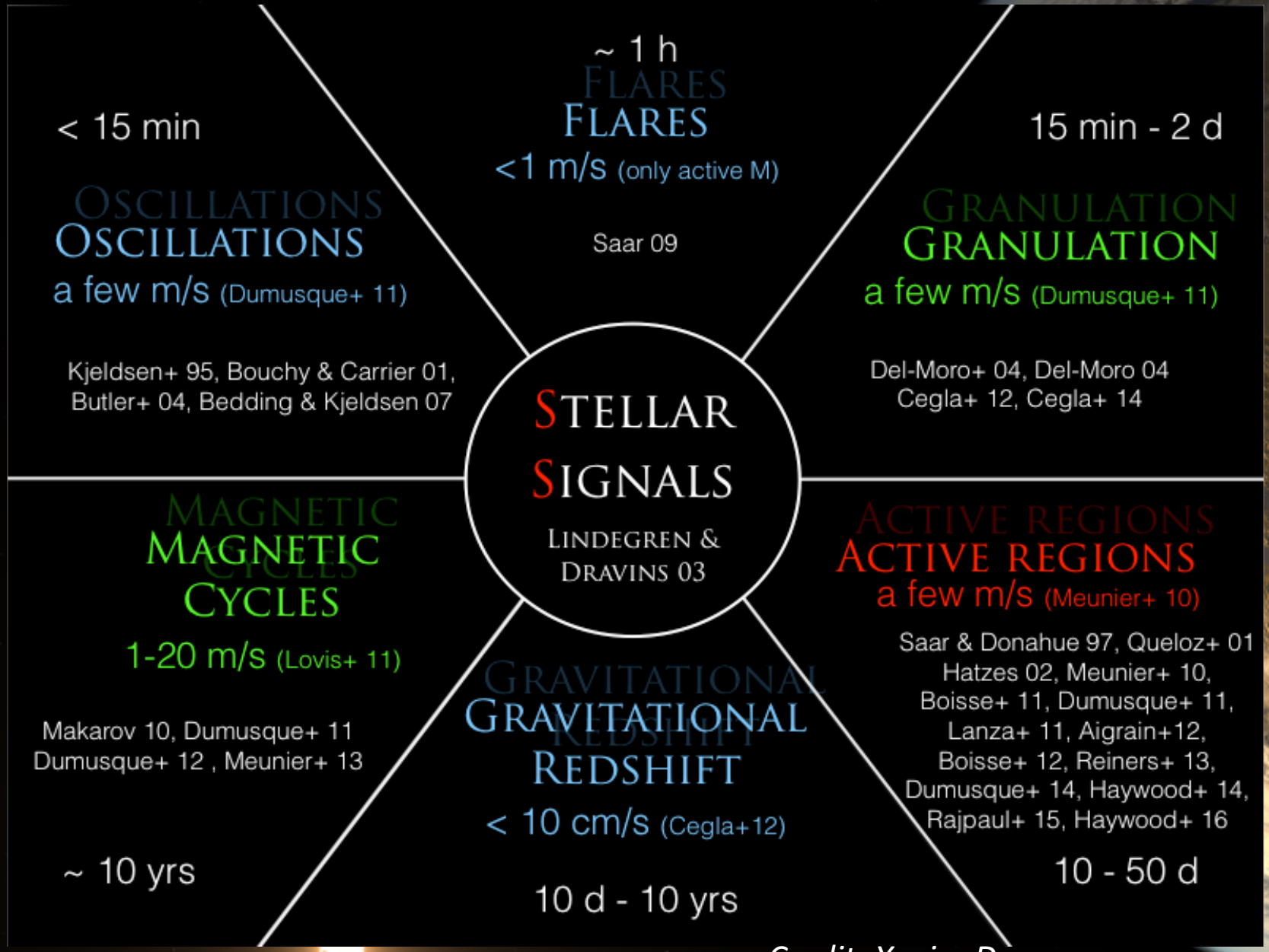
You can beat it down with longer integrations, but you still need to well sample the shape of the transit…

… basically the noise floor

So why didn't Kepler get there?



Stars do other stuff…

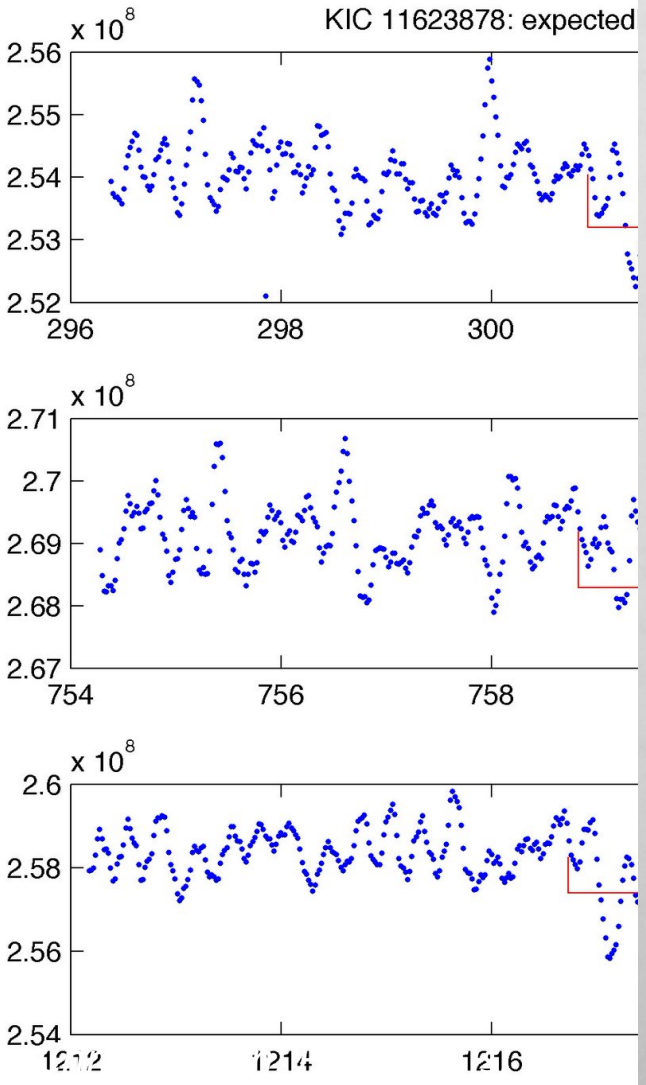


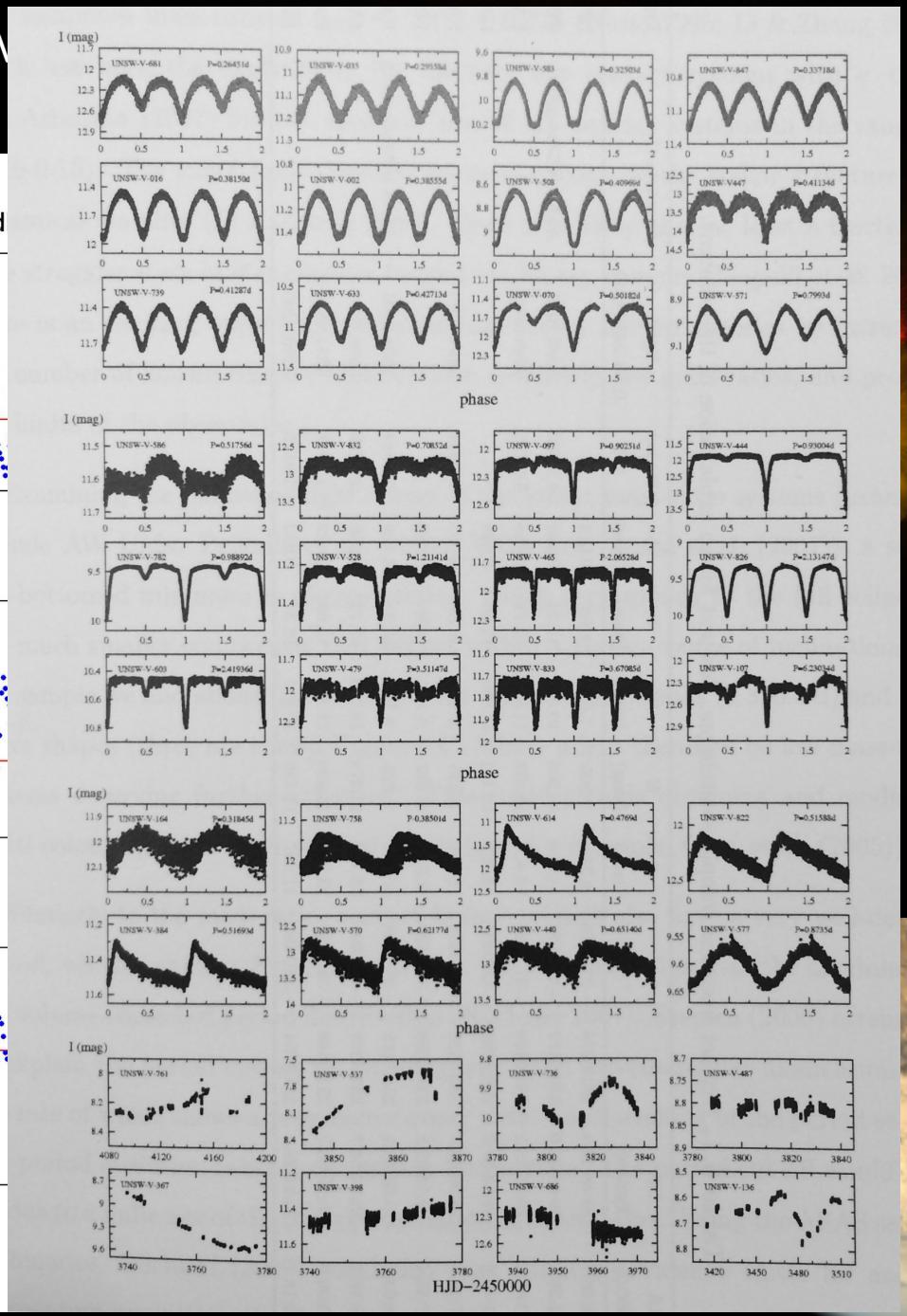
Credit: Xavier Dumusque

Stars do stuff...

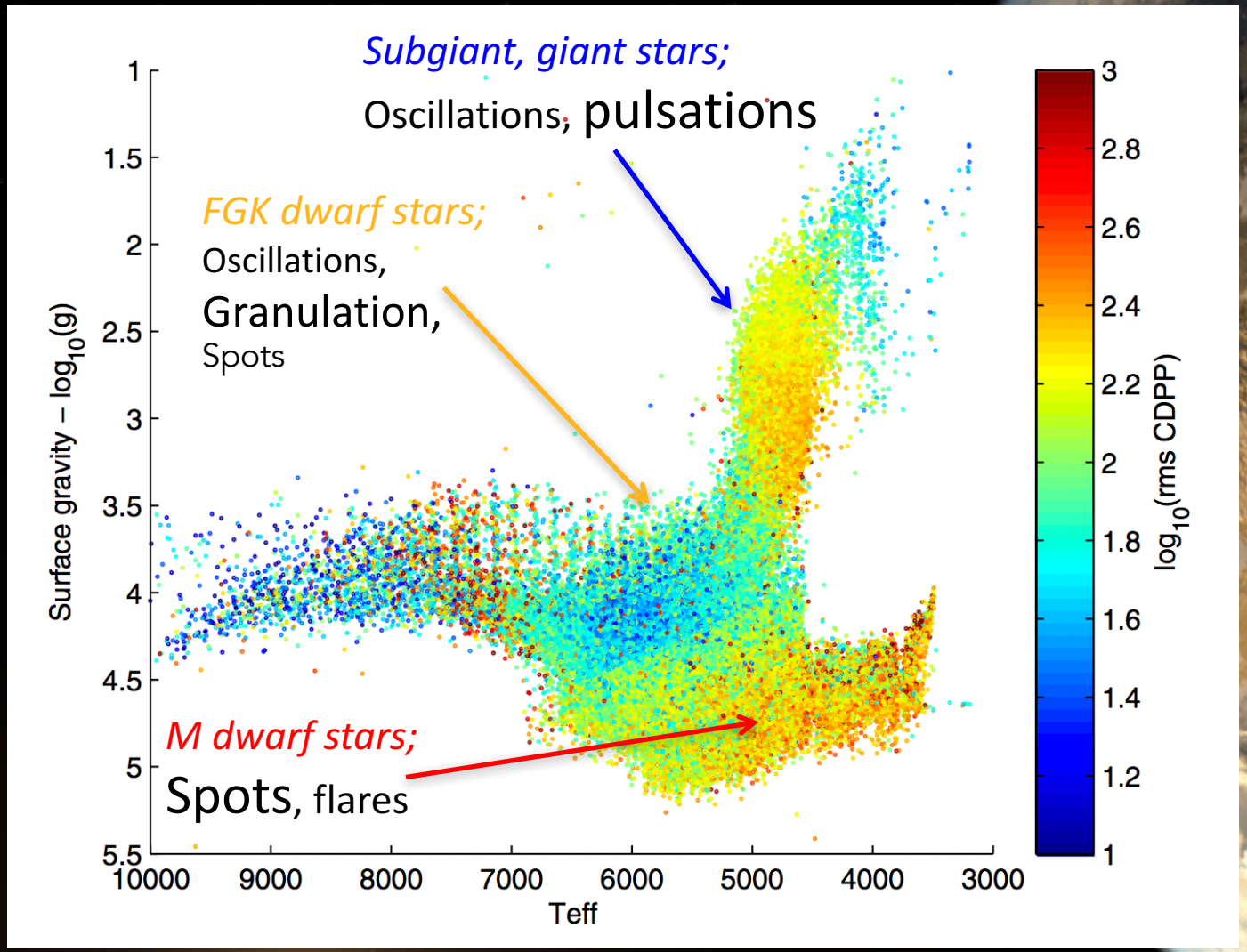
Credit: N

Osc





Different stars do different stuff…



Christiansen+2012

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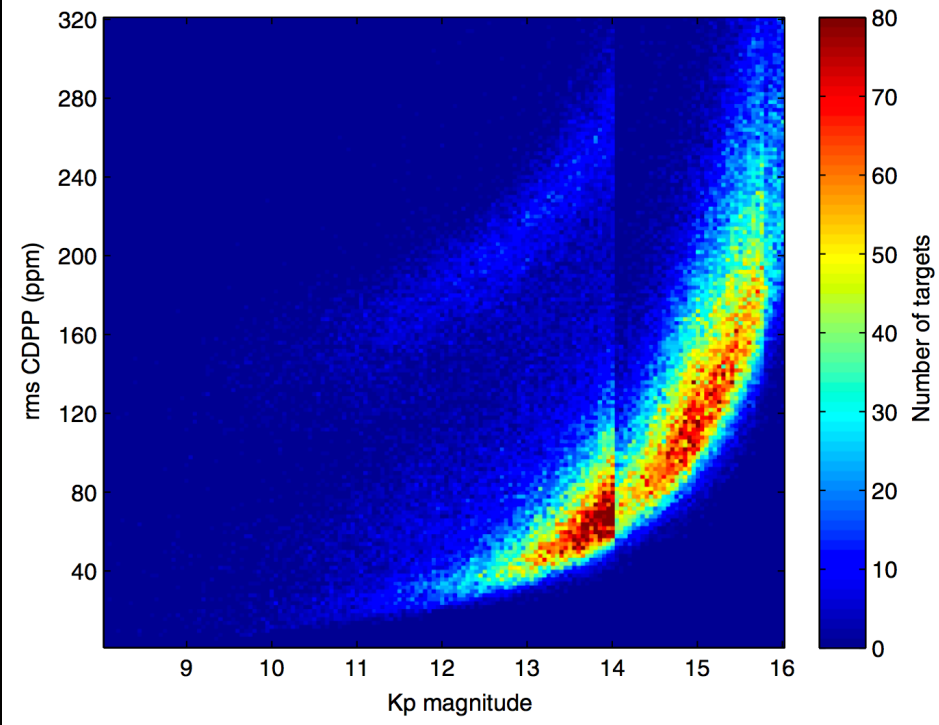
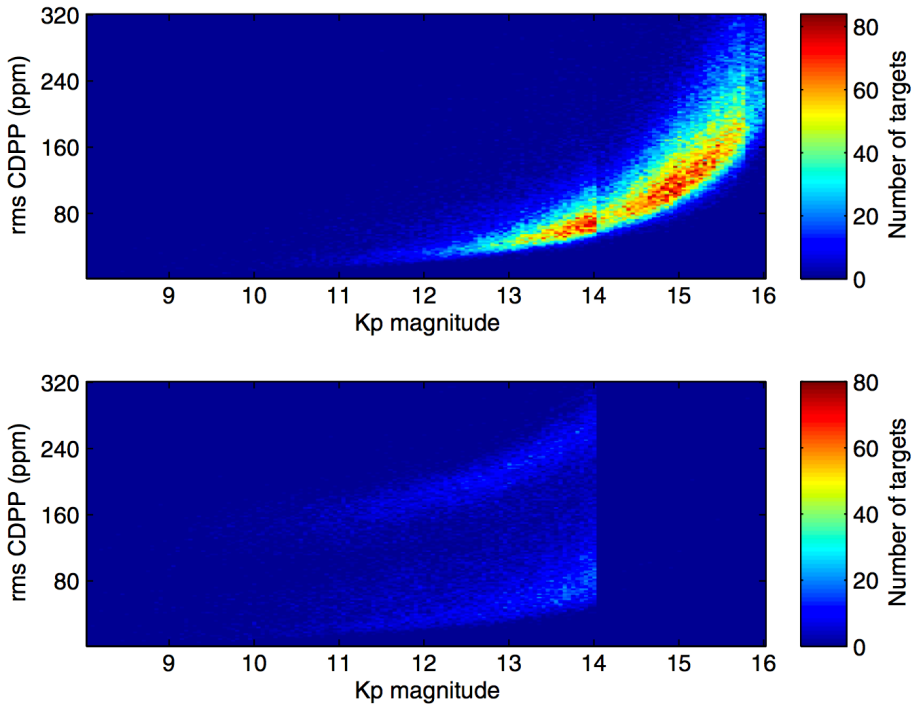


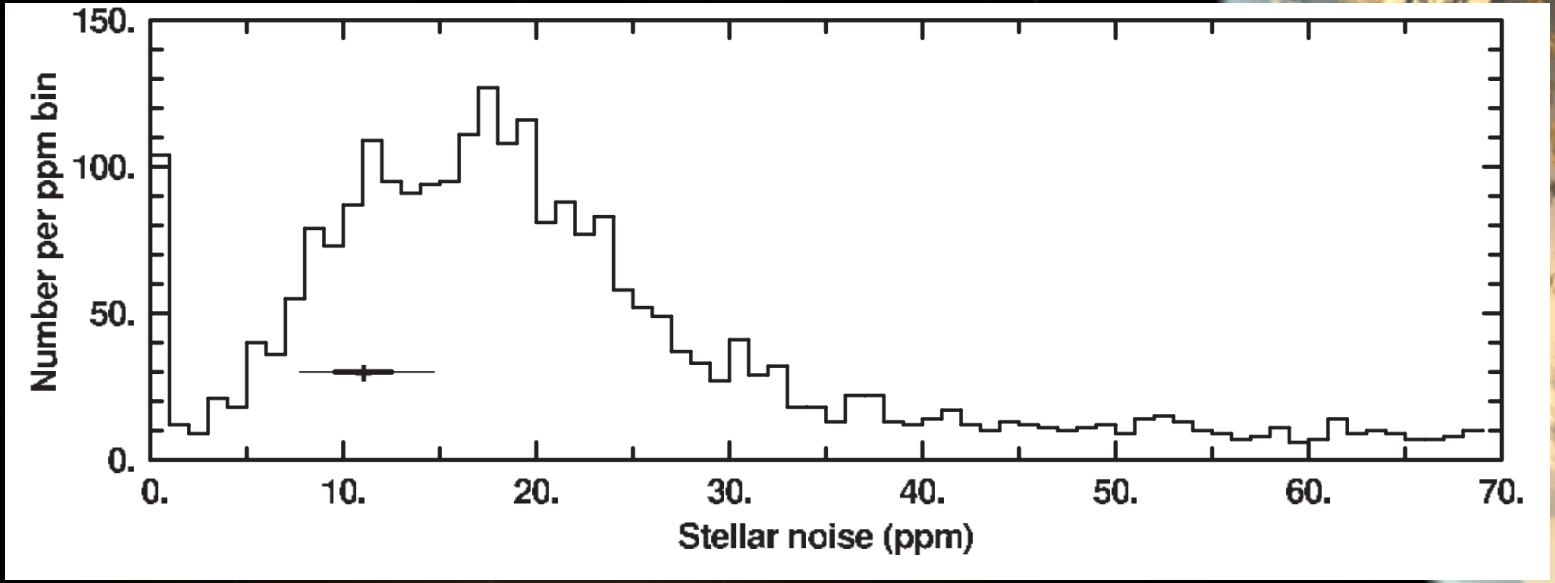


Christiansen+2012

So how did we do overall?

Kepler stellar noise budget – 10ppm

Turns out stars are noisier than the Sun!

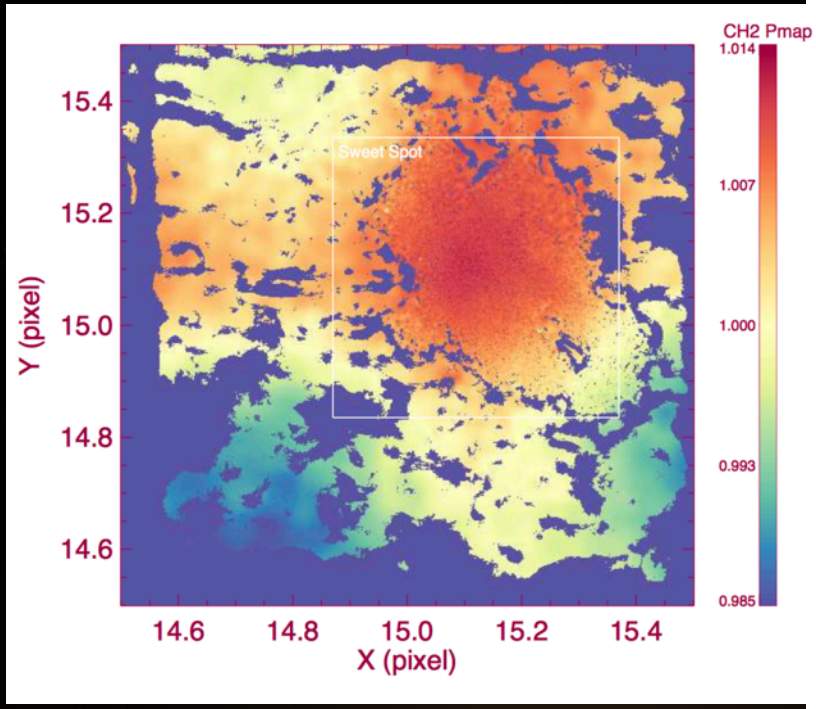


Gilliland+2011

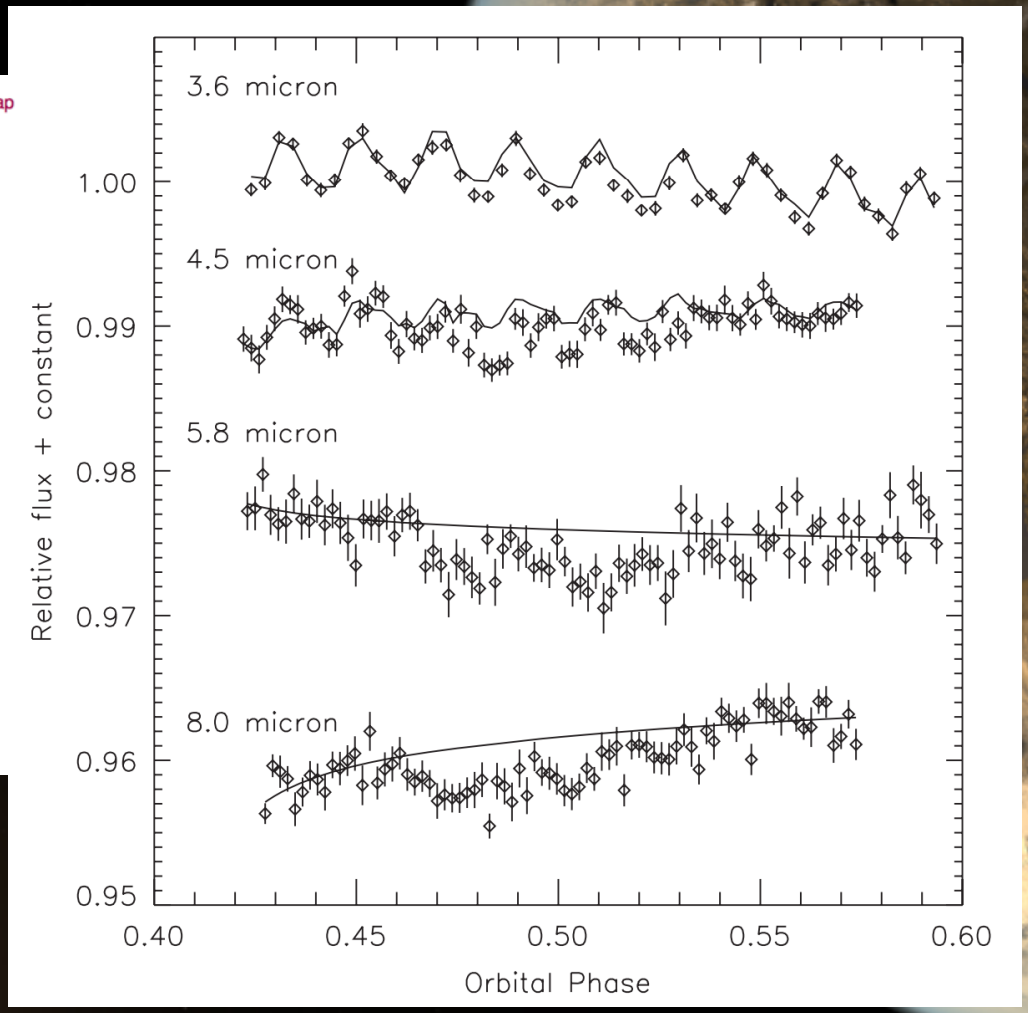
Telescopes do stuff…

They typically have pointing jitter

- Intra-pixel variations, e.g. Spitzer, K2 (not Kepler!)



irachpp.spitzer.caltech.edu



Christiansen+2010

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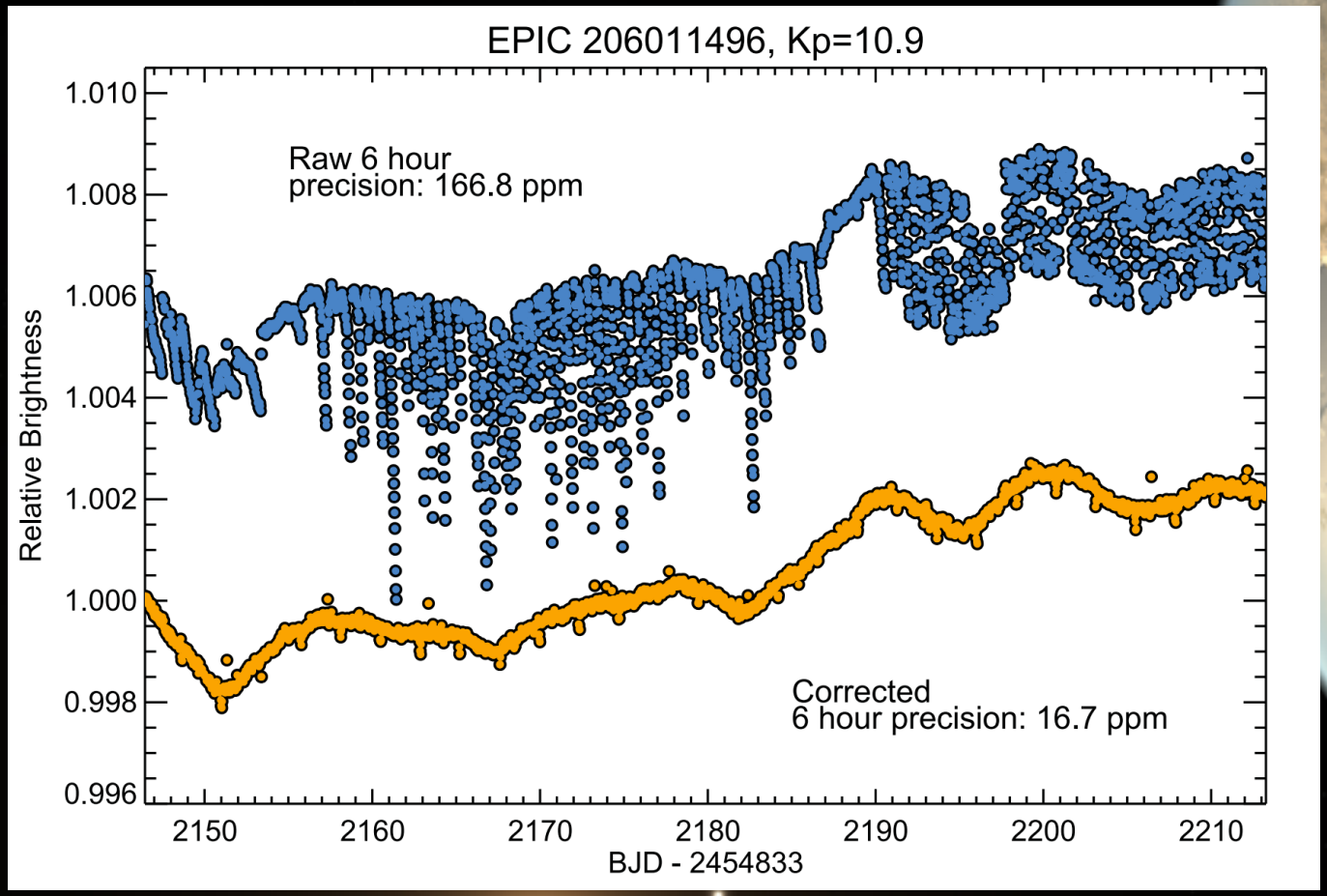
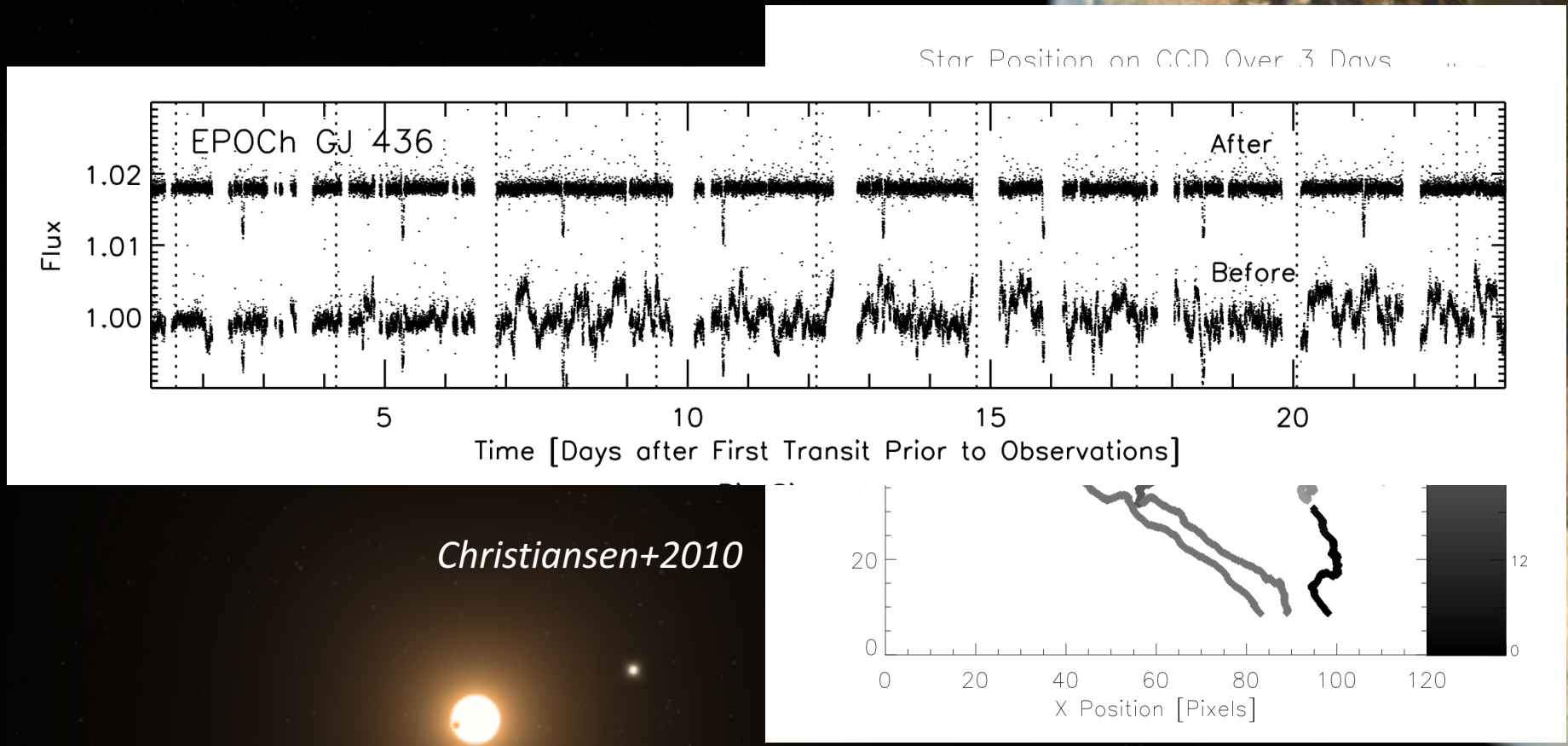


Vanderburg+2016

Telescopes do stuff…

They typically have pointing jitter

- Intra-pixel variations, e.g. Spitzer, K2 (not Kepler!)
- Inter-pixel variations, e.g. EPOCh



Christiansen+2010

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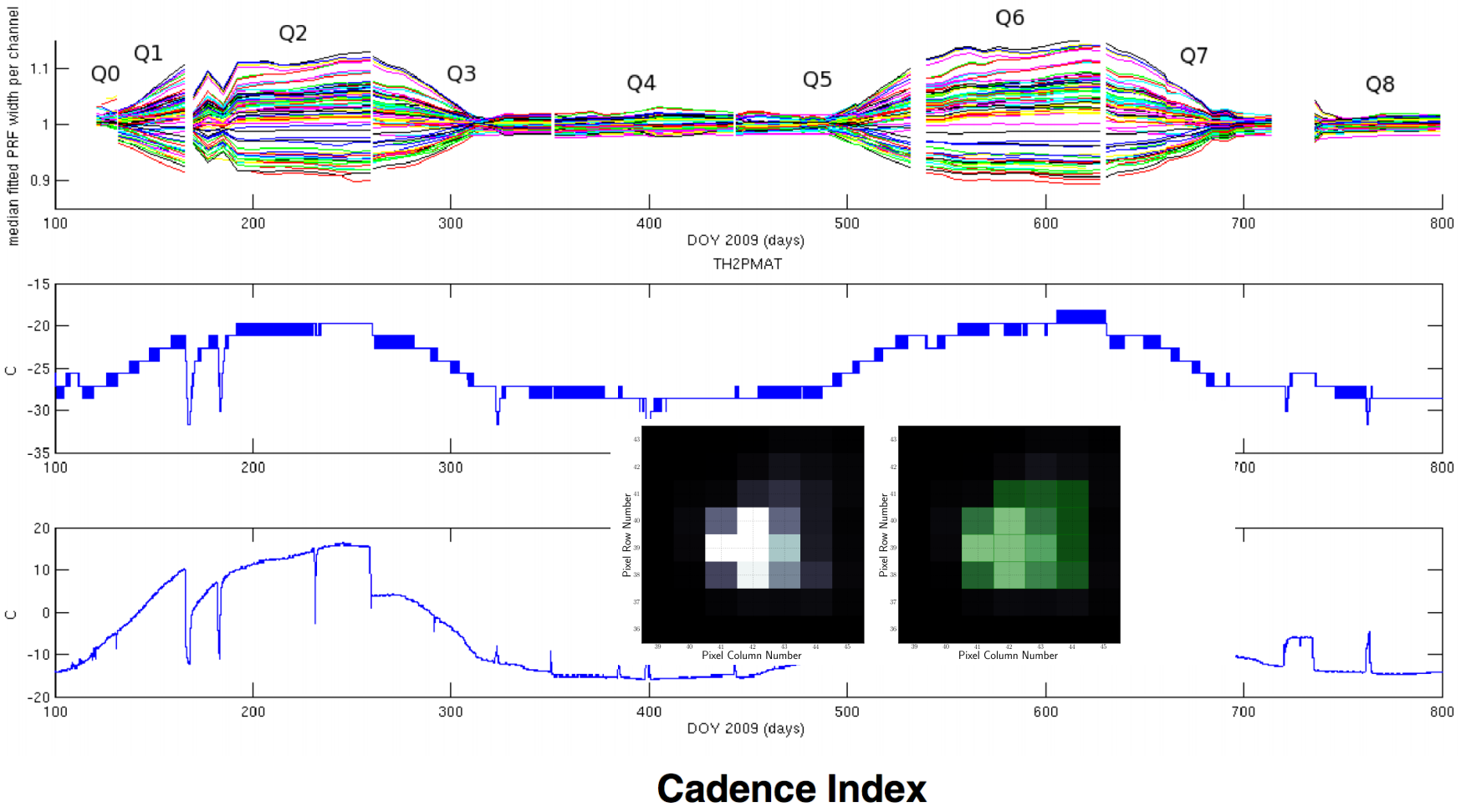
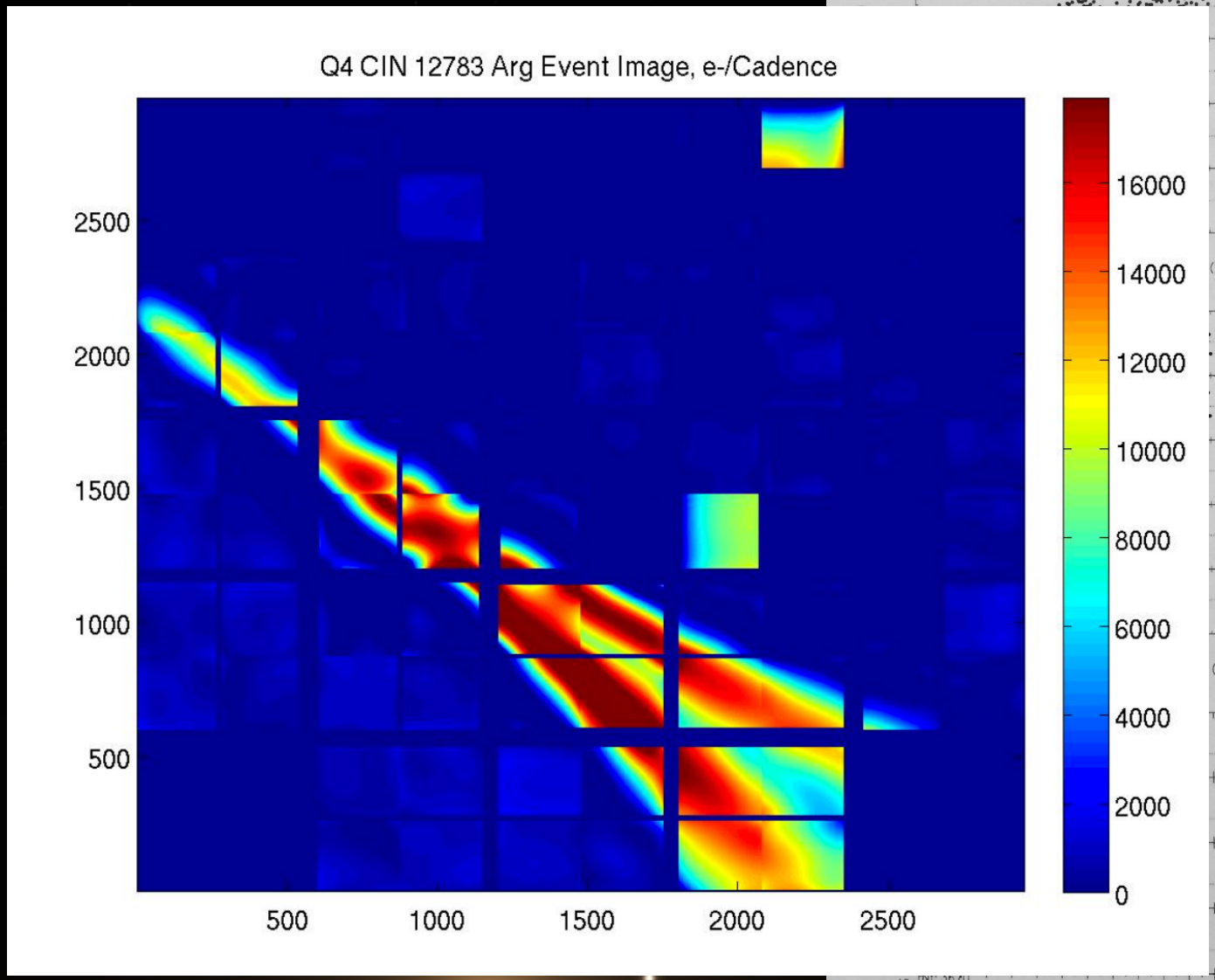
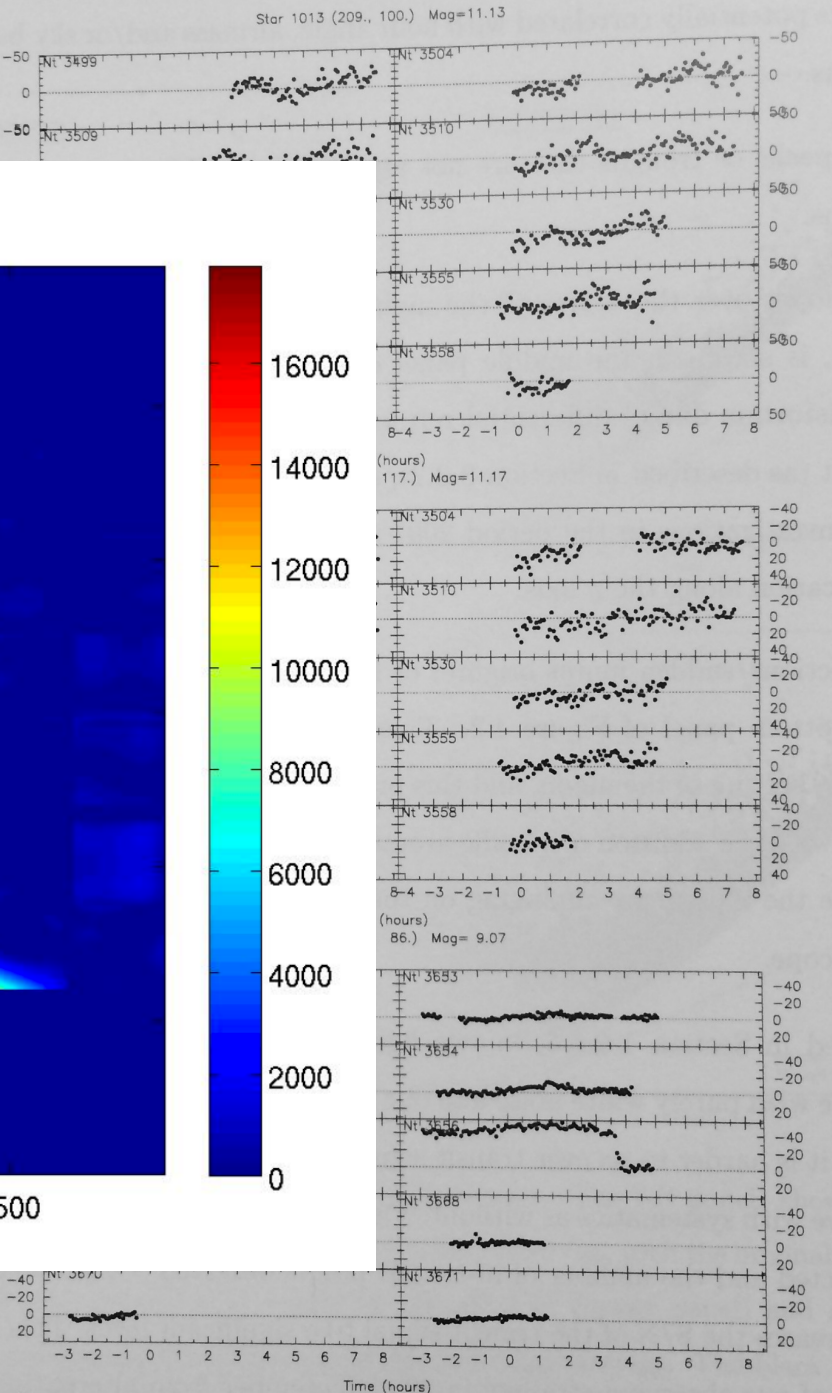


Smith+2012

The atmosphere does stuff…





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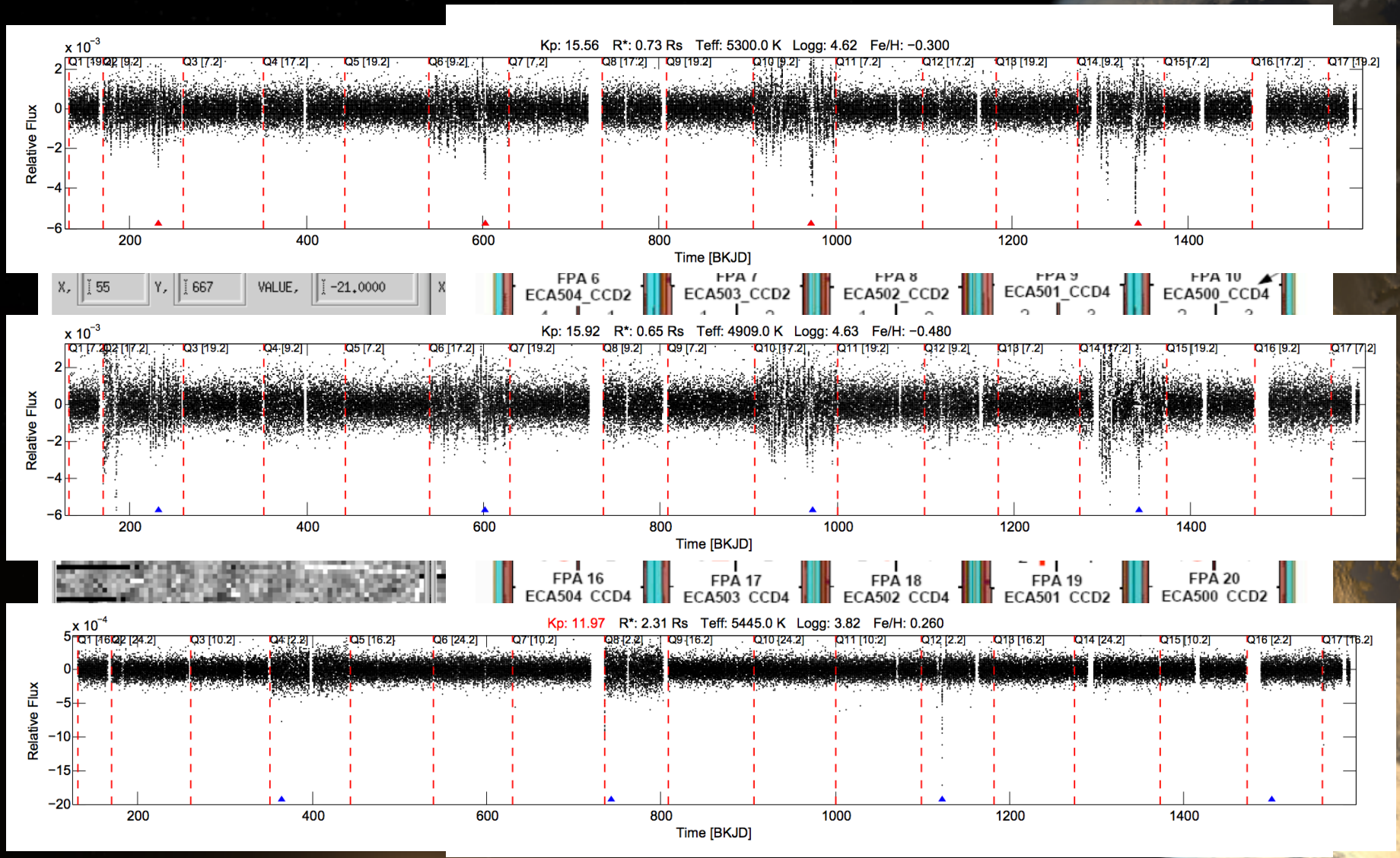
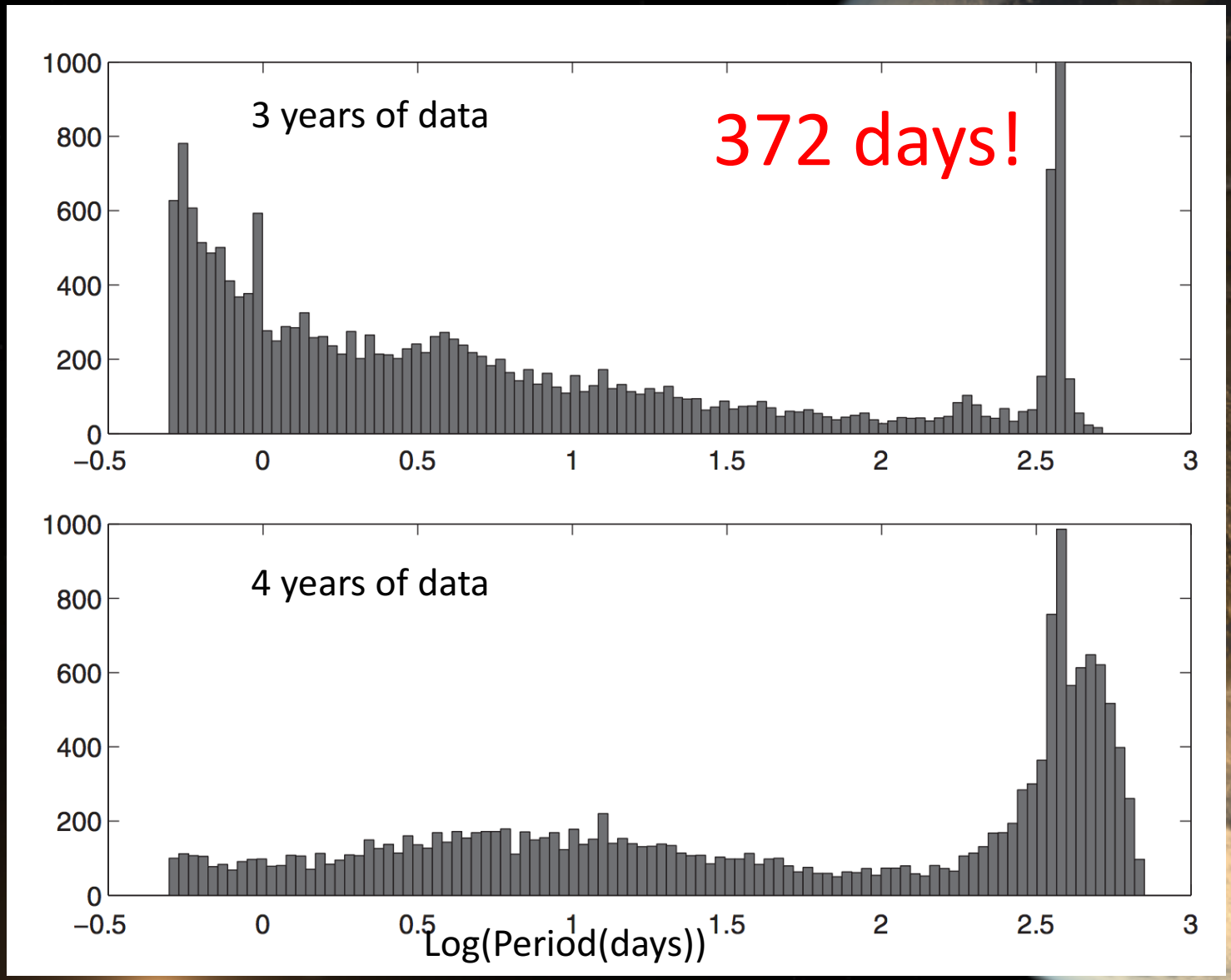
Kepler Instrument Handbook, Caldwell & Van Cleve 2009

Detectors do stuff…

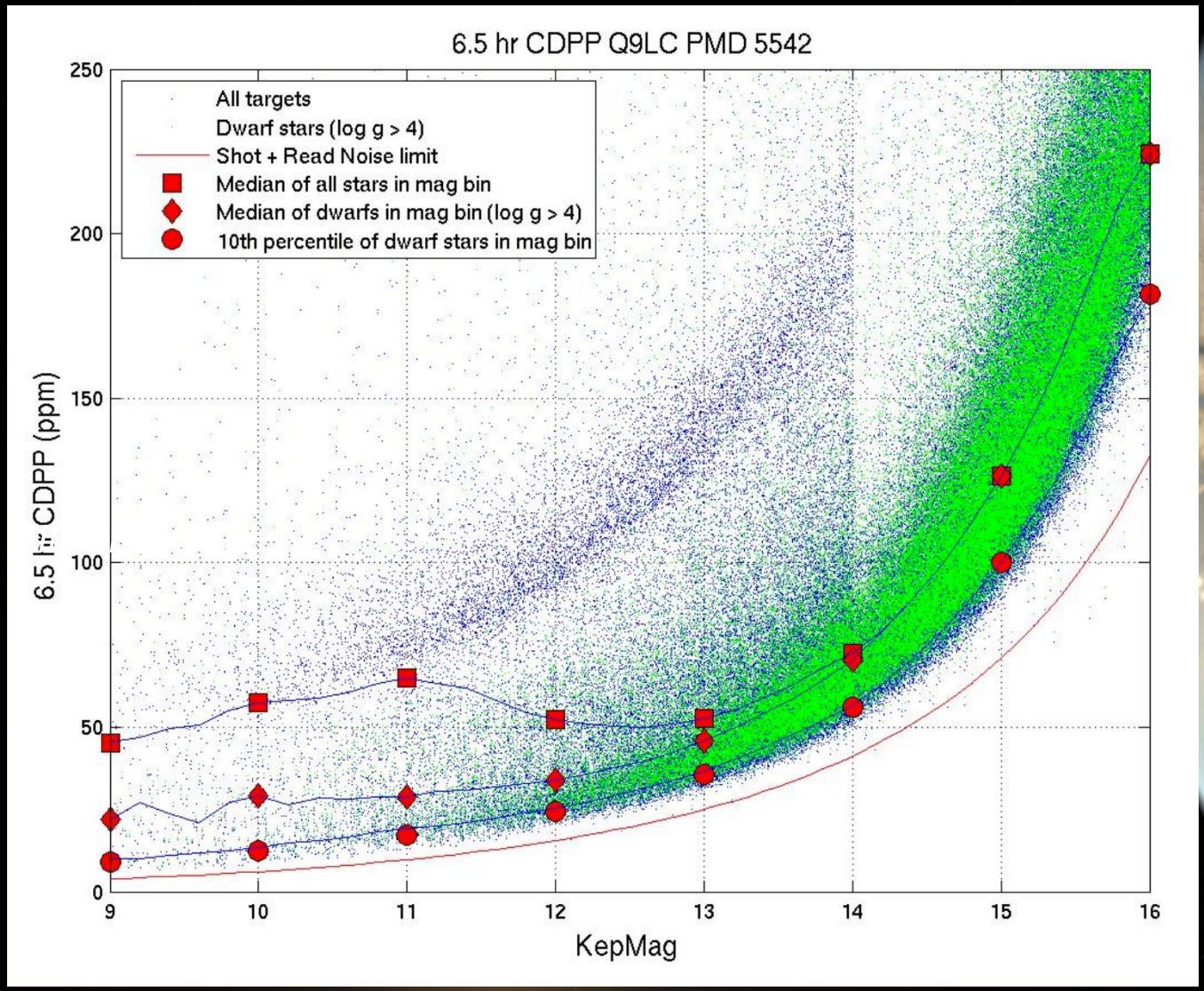


Detectors do stuff…



Tenenbaum+2014

Final noise contribution

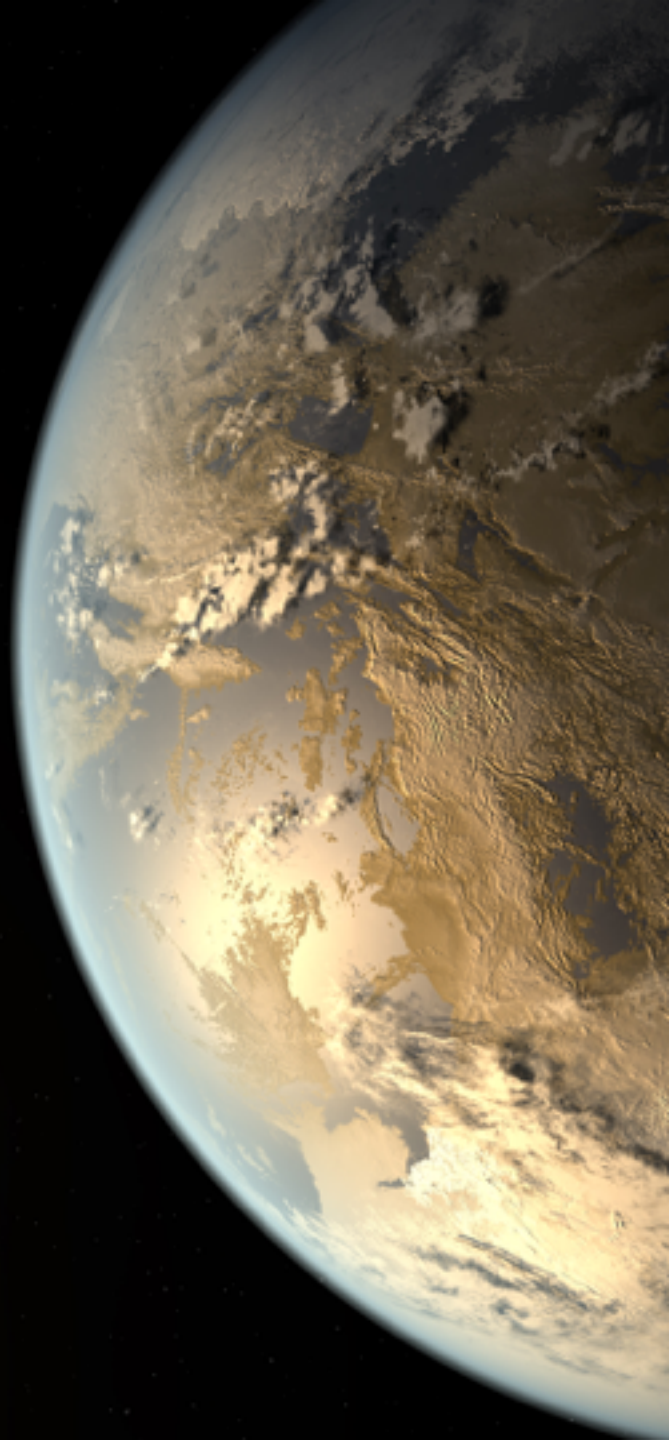


Christiansen+2013

Summary

There is a lot standing between you and a clean transit signal!

You can make clever choices in order to minimise/mitigate/isolate noise sources (or at least the timescales of those noise sources)

- Target selection
- Stability of instrument
- The more the merrier, for treating common mode systematics

For remaining (and sometimes unavoidable) noise sources, exoplaneteers have been relying on increasingly sophisticated noise models (e.g. Gaussian process) – see rest of #sagan2016!