
From *Kepler*/K2 to TESS

- TASC data preparation -

TASC Working Group 0 (WG0)

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Chairs: Rasmus Handberg & Mikkel N. Lund

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- Pixel level calibrations + corrections
- Extract light curves (all 20-sec + 2-min + 30-min FFIs)
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Kepler - TESS comparison

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- Cadences from 6-sec integrations
- ~160.000 long-cadence (LC; 29.4 min)
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- >200.000 2-min
- >20.000.000 30-min (FFI)
- ~60 20-sec per sector for seismology
- ~750 2-min per sector

2 year mission



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- TESS 2-min data → ~13x data rate of *Kepler* (Jenkins et al., in prep.)
- TESS 2-min + FFIs → ~25x data rate of *Kepler*
- Processed data products → ~12x raw data (@ MAST for *Kepler*)

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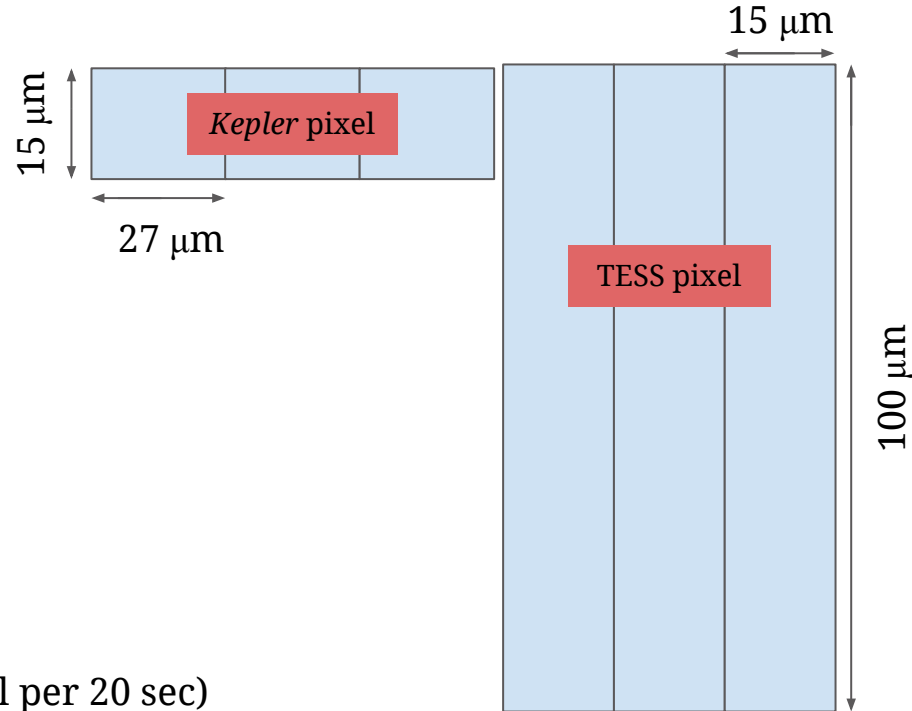
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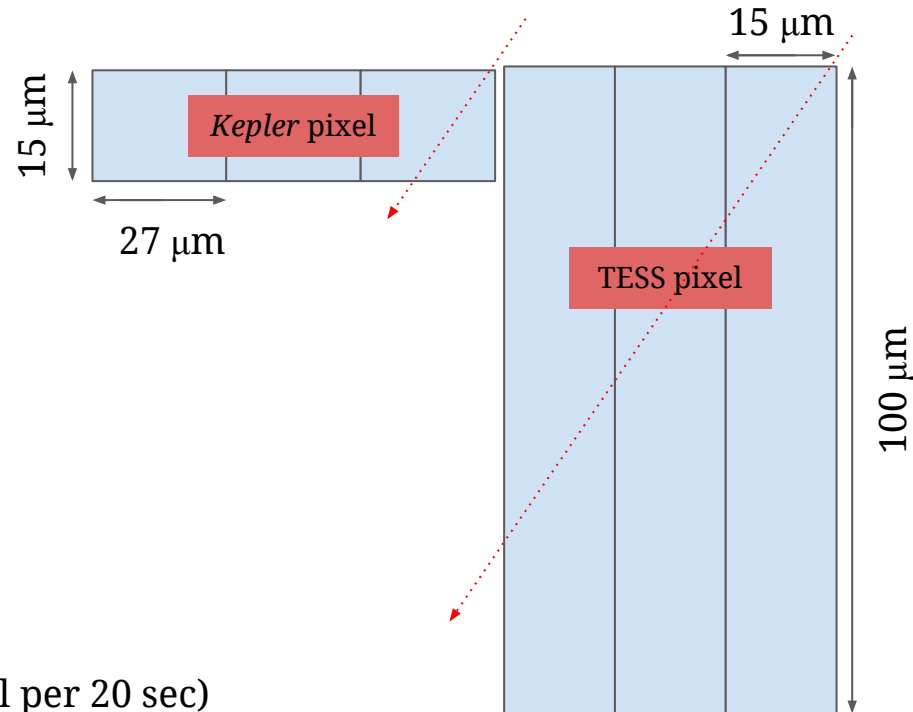
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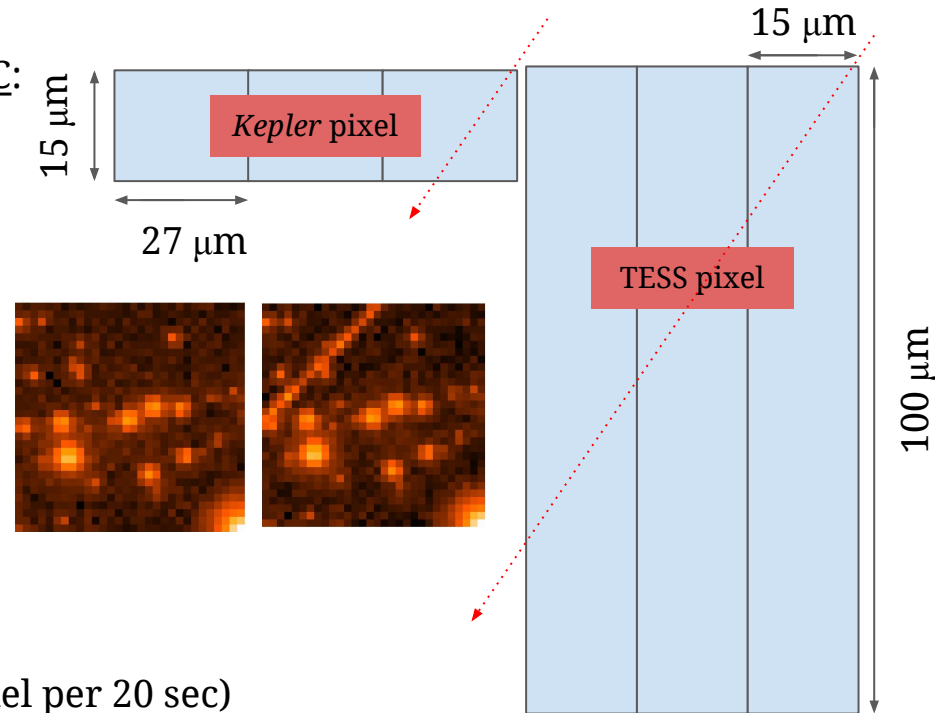
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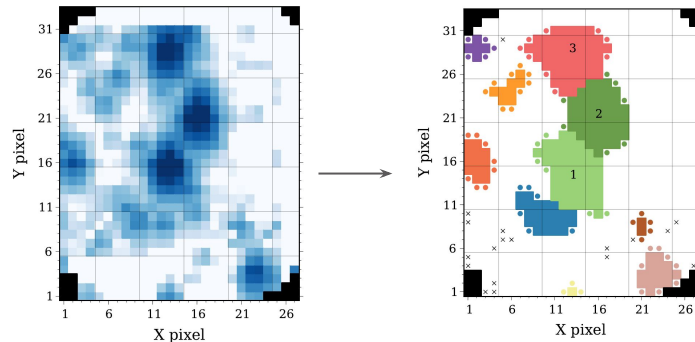
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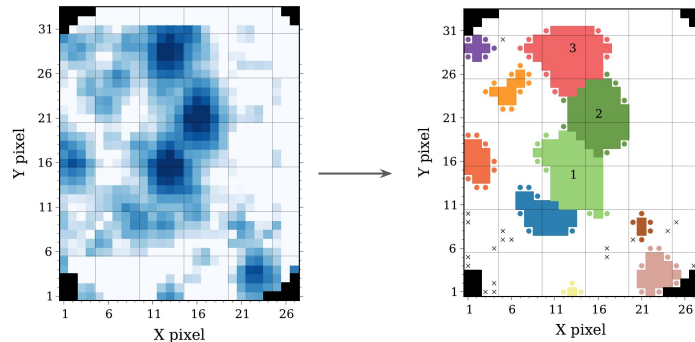
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Tests of methods on simulated TESS pixel data from `SPyFFI`, developed by Zach Berta-Thompson (MIT)

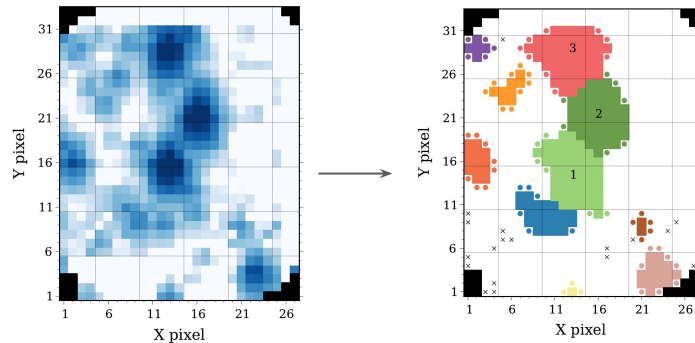


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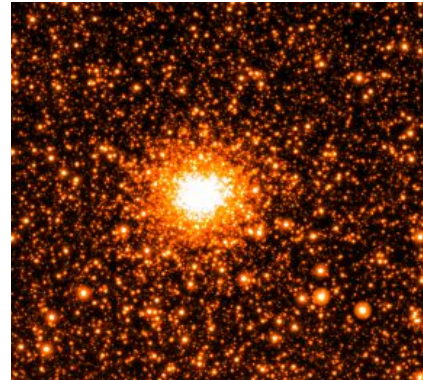
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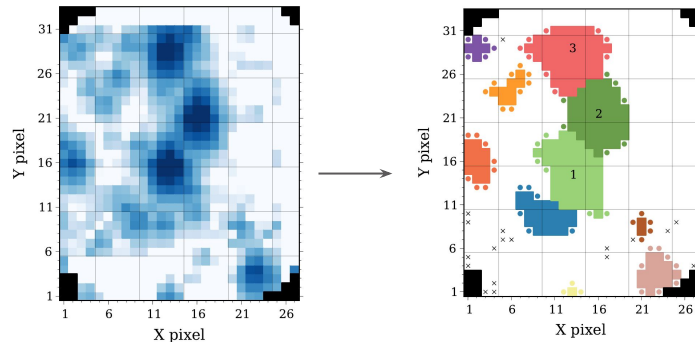
ω Cen (NGC 5139)



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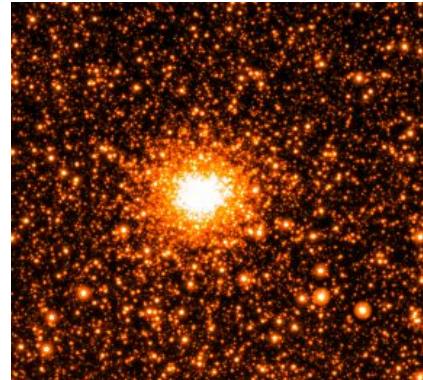
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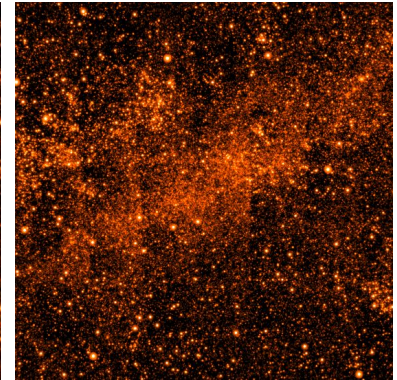
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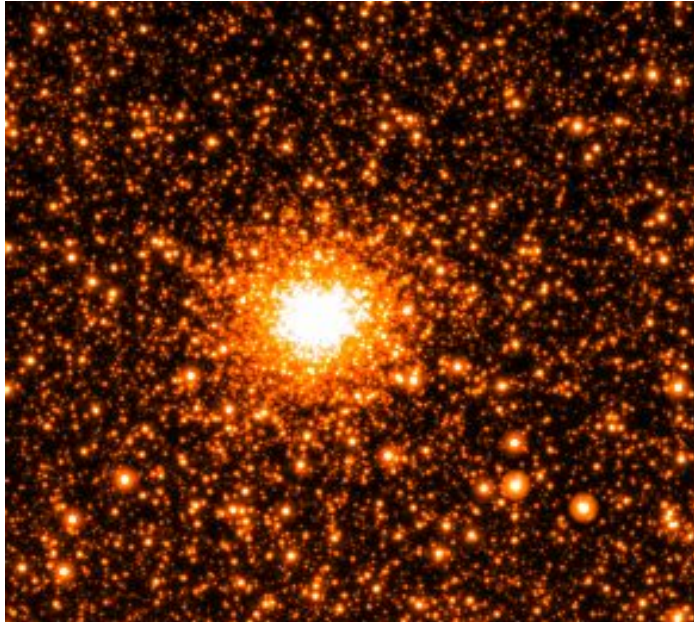
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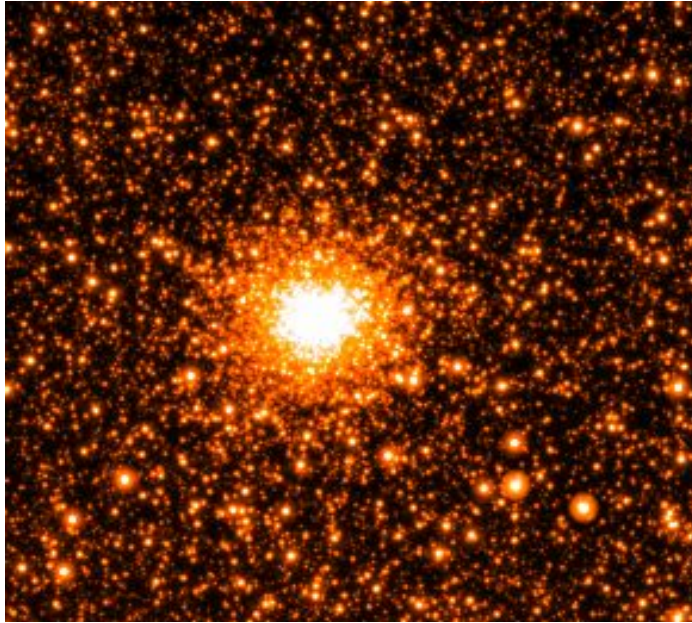
LMC



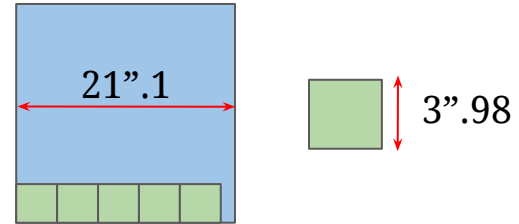
TASC WG0 - Data extraction



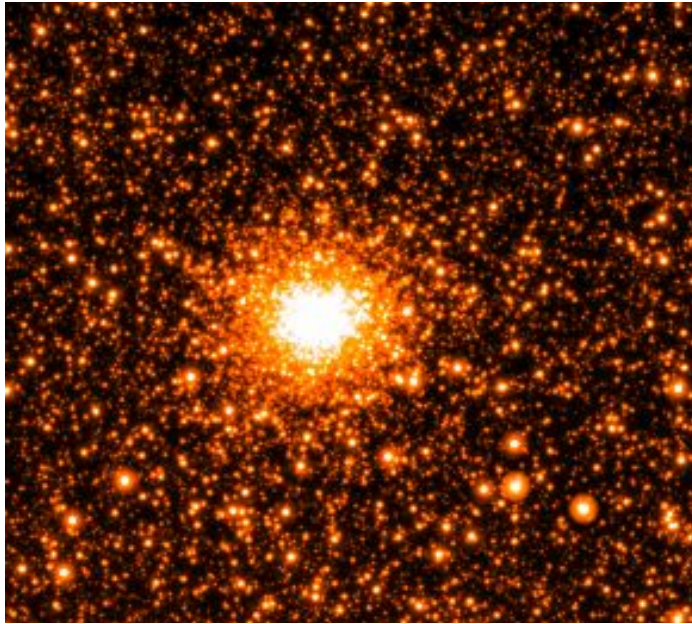
TASC WGO - Data extraction



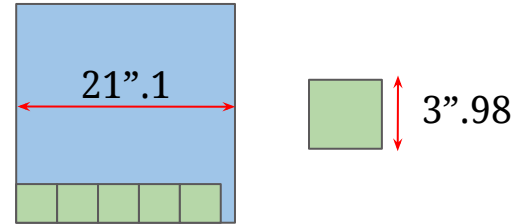
Pixel sizes



TASC WGO - Data extraction



Pixel sizes



Pixel response function

50% light within one pixel
90% light within 4×4 pixels



Very similar
to *Kepler*

- off-axis and chromatic aberrations
- $\lesssim 1''$ rms jitter

TASC WGO - Light curves

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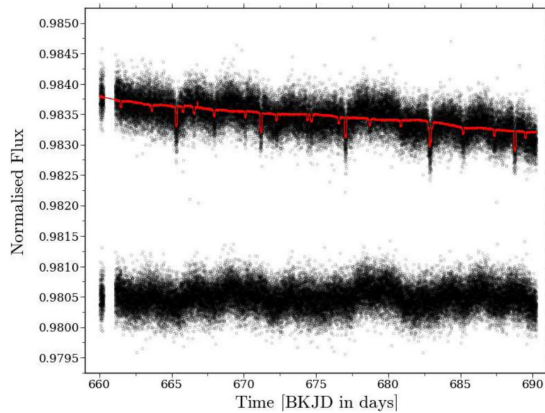
Light curve preparation

- Star-type specific corrections

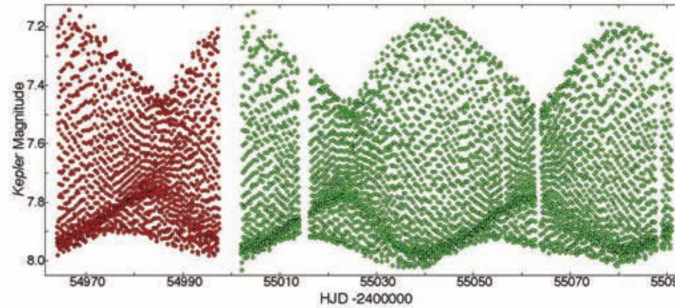
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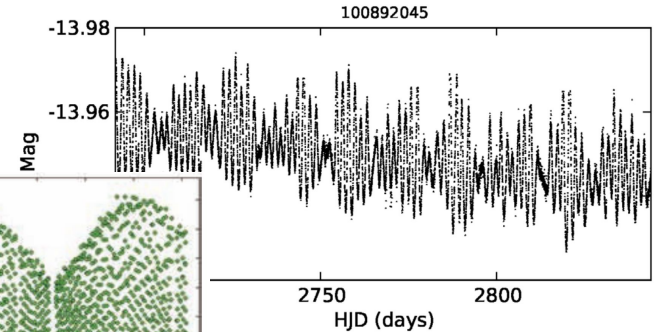
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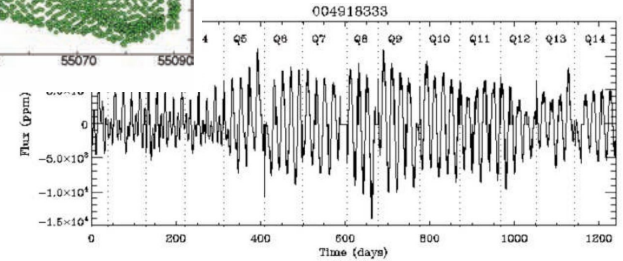
Credit: Handberg & Lund (2014)



Credit: Kolenberg et al. (2011)



Credit: Debosscher et al. (2009)



Credit: Garcia et al. (2013)

TASC WGO - Light curves

Light curve preparation

➤ Star-type specific corrections

- Preserving astrophysical signals
- Spots/rotation
- Transiting exoplanets
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- Mitigating systematic effects

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See poster S3 #13 by
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- SPOC: full analysis of 2 min targets; aims at same structure of data products as for *Kepler* (Jon Jenkins et al.; in prep.)

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WG0 workshop series:

“TESS Data for Asteroseismology 1 - from pixels to light curves” (T’DA1) in Birmingham in the fall 2016.

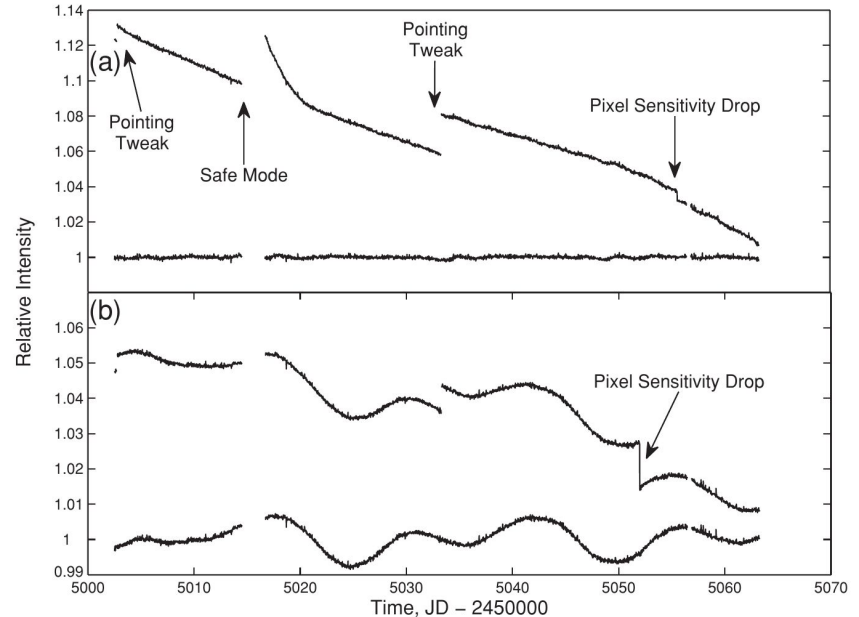
T’DA2 on light curve corrections planned to take place in Aarhus, spring 2017.



TASC WGO - Light curves

Light curve preparation

- Mitigating systematic effects
 - Co-trending Basis Vectors (delivered by SPOC)
 - Gaussian processes
 - Causal data driven models
 - Robust “high-pass” filters
 - Processing speed vs. data vol.

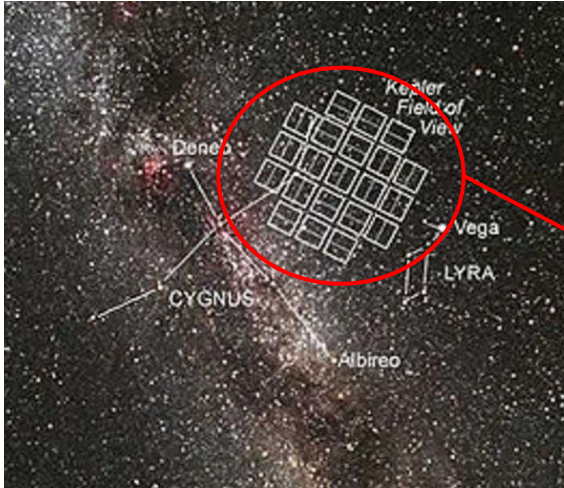


Credit: Jenkins et al. (2010)

Kepler - TESS comparison

Kepler

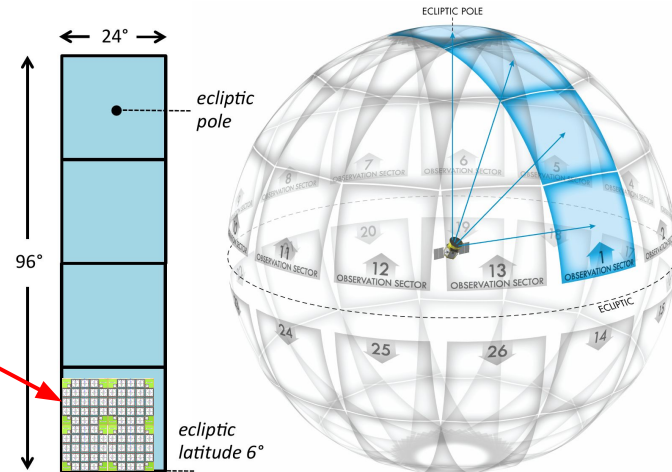
- $\sim 10^\circ \times 10^\circ$ field-of-view (FOV)
- 42 CCDs



Credit: NASA

TESS

- $24^\circ \times 96^\circ$ FOV
- 4 cameras, each with 4 CCDs

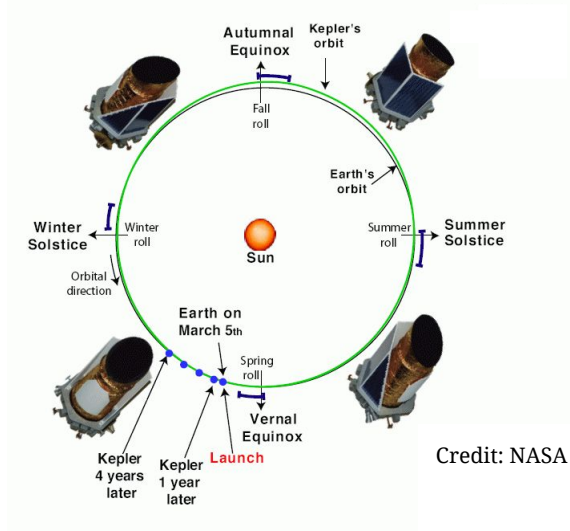


Credit: Ricker et al. (2014)

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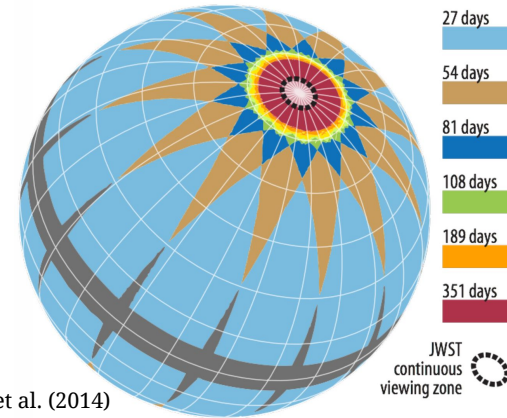
Kepler

- Data every ~3 months (a “Quarter”)
- K2 data every ~80 days (a “Campaign”)



TESS

- New sector every 27.4 d (2 orbits)
- Downlink every 13.7 d (1 orbit)
- CVZ covers ~450 deg²
- (Restart at nearest integer 2-min cadence)



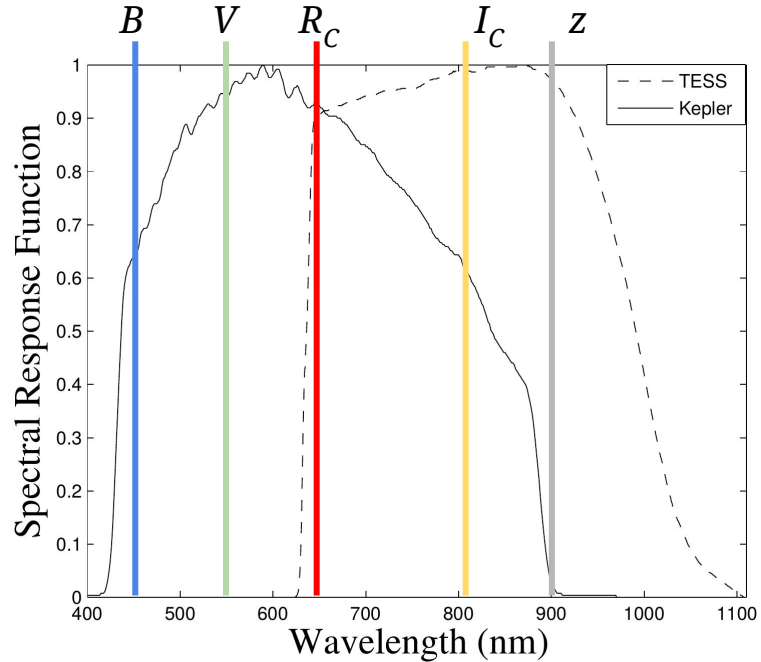
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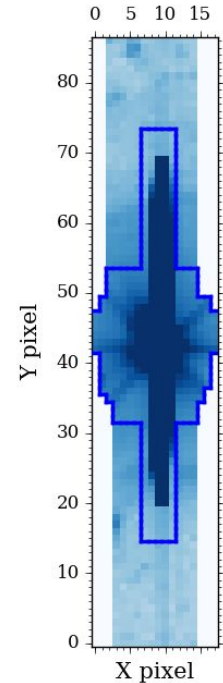
- Kepler mag (Kp) $\sim R_C$
- Saturation at Kp ~ 11.5

TESS

- TESS mag $\sim I_C$
- Saturation at $I_C \sim 7.5$
- (Charge conservation until $I_C \sim 2.5$)



Credit: Placek et al. (2016)



TASC WGO - Time calibration

- The on-board TESS clock should be accurate and stable to better than ~ 5 msec
- Correction to Barycentre should have same accuracy

Absolute time calibration?

- Comparison of stellar oscillations between TESS and ground-based observations
 - Bright high-amplitude short-period coherent pulsators ($\sigma_t \sim 0.5$ sec)

Regular calibrations using contemporaneous observations with TESS and, e.g., SONG of bright detached eclipsing binaries (in CVZs)

BSc work by Jonas S. Hansen and Andreas K. Dideriksen (AU, DK)

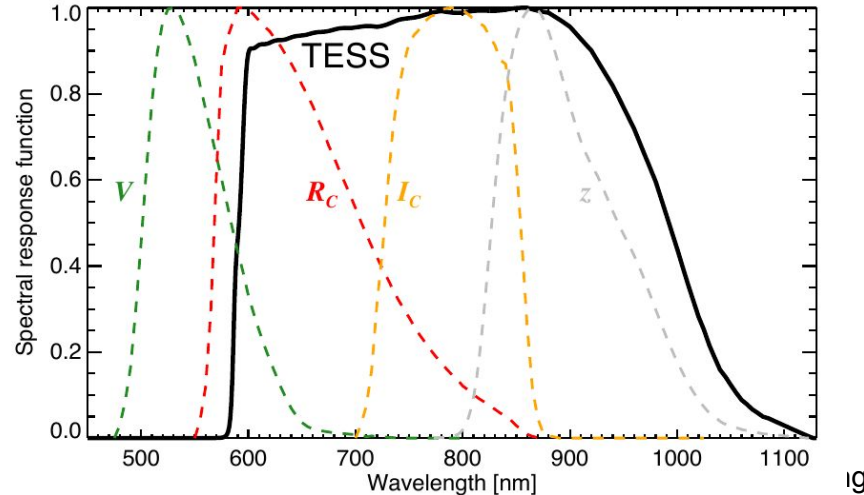
→ $\sigma_t \sim 0.5$ sec achievable with only few bright EB transits

Kepler - TESS comparison

Expected noise properties

Noise properties

- Contributions:
 - Zodiacal noise (ecliptic)
 - Photon shot noise (magnitude)
 - Inst. noise (read noise, pointing error - attitude system, velocity aberration effects, and mechanical long-term drifts in the electronics)
- Rule of thumb: Factor 5 in magnitude calculation)
- Pointing error rms $\sim 1''$ (small comp. To pixel size)



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