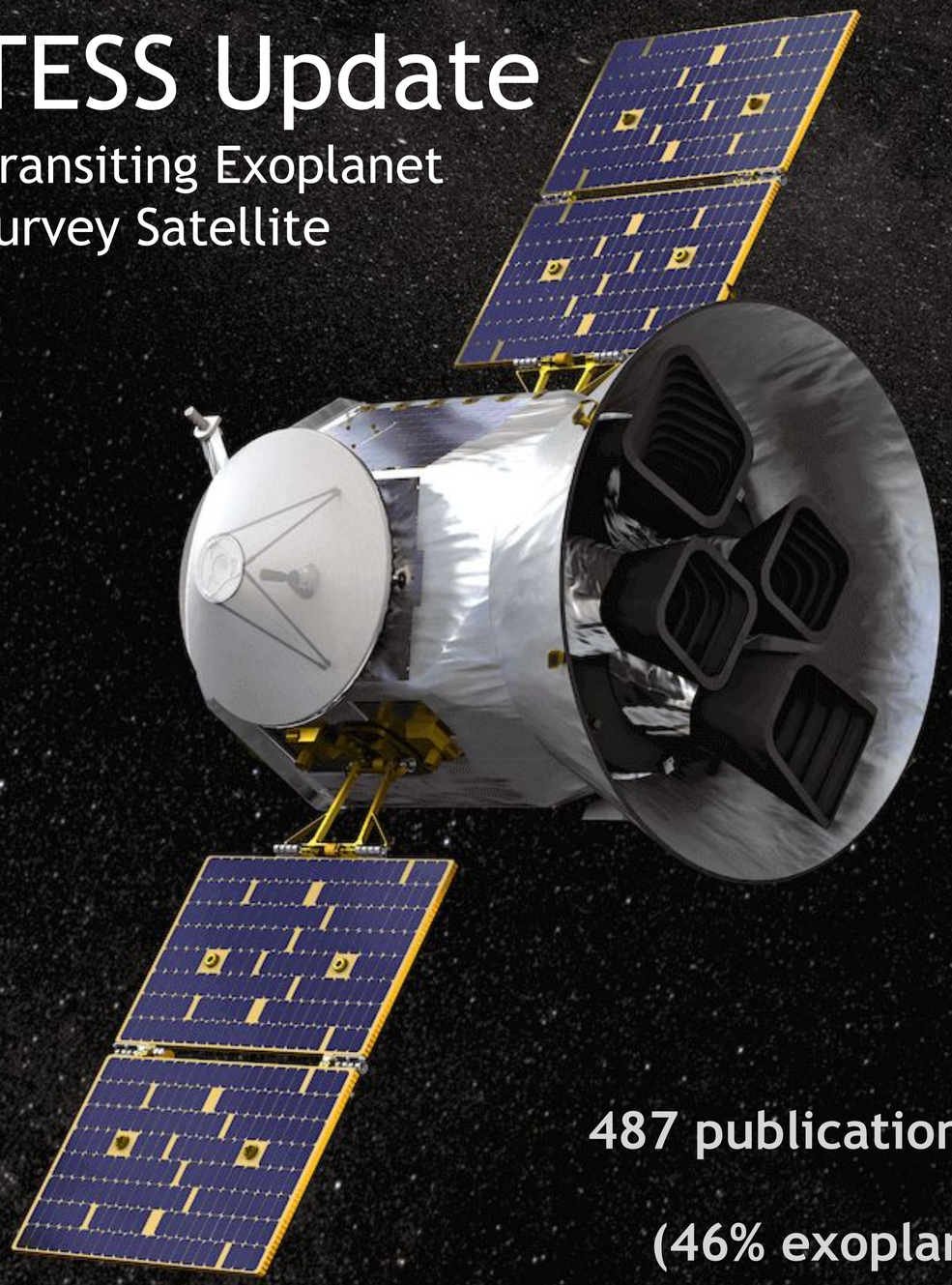
TESS Update

Transiting Exoplanet
Survey Satellite



Extended Mission Began
July 5, 2020

Observation Sector 33
2020 Dec 18 -2021 Jan 13

91 confirmed planets
2440 planet candidates

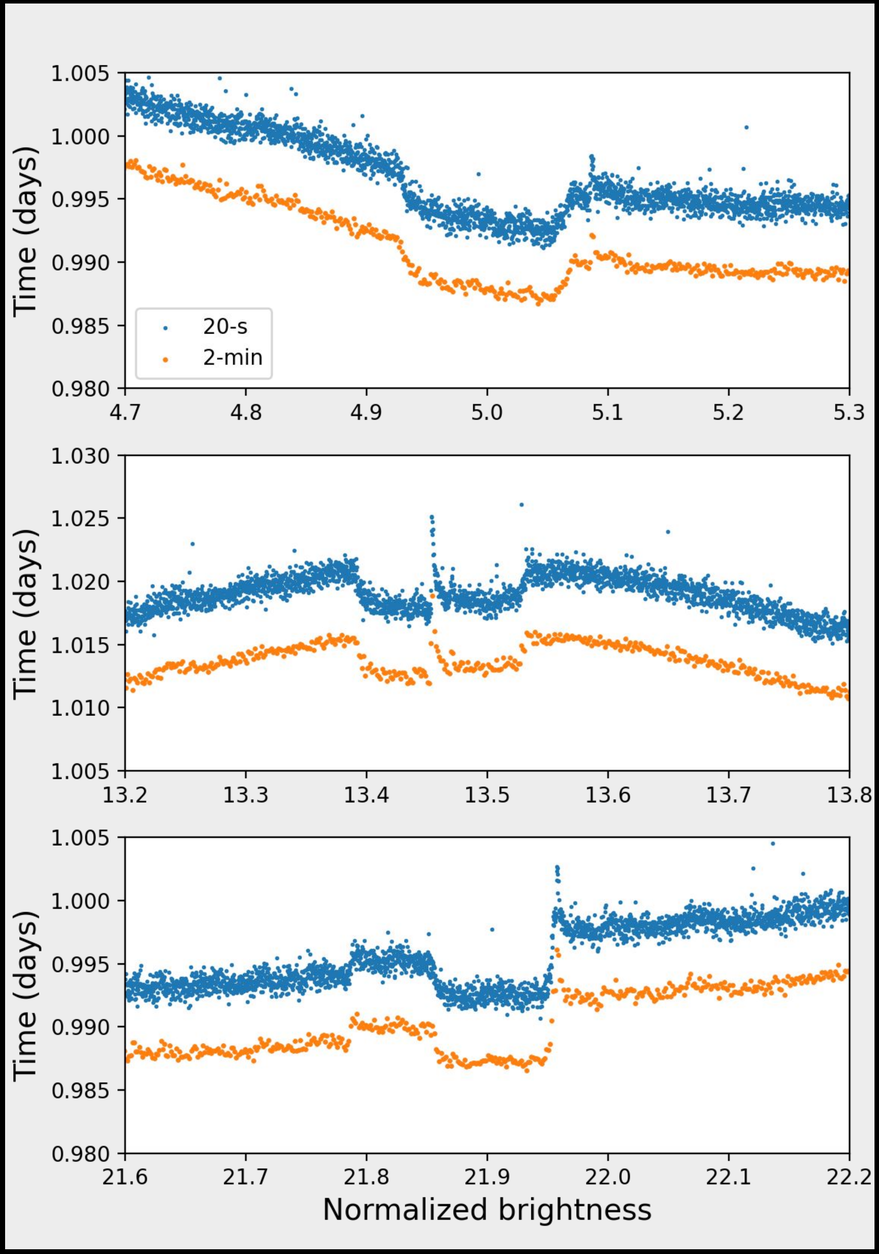
487 publications submitted, 389 peer-reviewed

(46% exoplanets, 54% astrophysics)

Last update: Jan 04, 2021

COVID-19 related shutdowns hit right in the middle of Sector 22, Since then…

- 11 Sectors have completed successfully, during mostly-mandatory telework
- Operations teams (POC, SPOC, TSO, MAST) and science/mission support teams (SSMO, NGSS, TFOP, NExScI, GI Office) still hunkered down at home yet working together productively
- Transitioned from Prime to Extended Mission!
- Zoom, WebEx, MicroSoft Teams working well for communication
- Team has done a remarkable job responding flexibly to challenges such as minimal on-site support staff, ground-based observatory shutdowns and changing from in-person activities to the virtual environment



Extended Mission: Sector 27 AU Mic transits, Flares, 2min and 20-s data

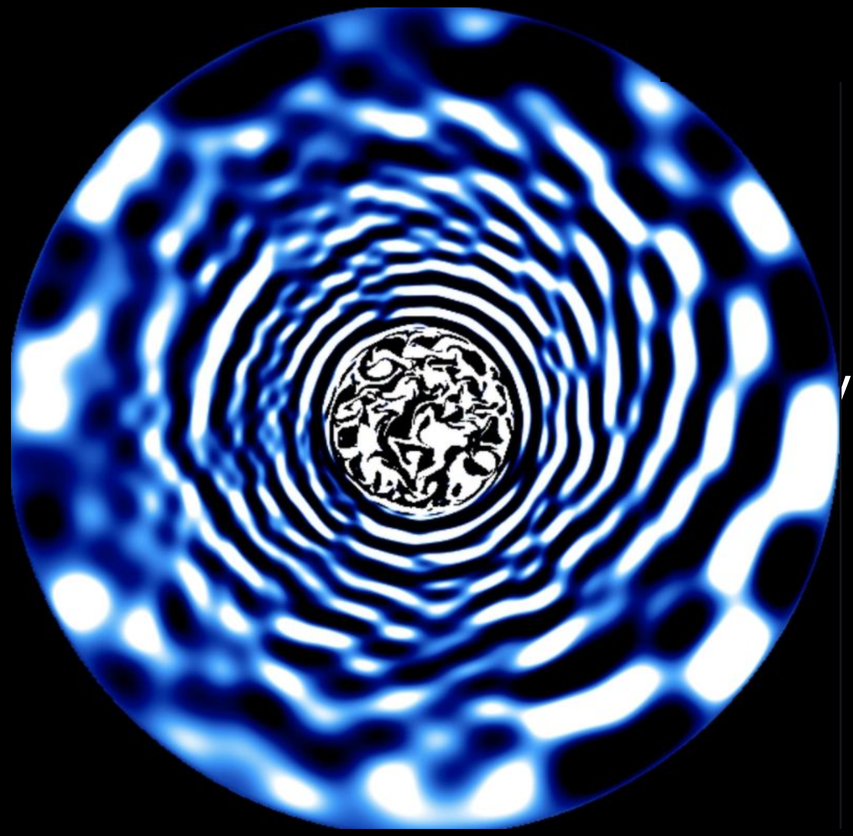
Peter Plavchan et al.
Nature 2020

https://exoplanets.nasa.gov/resources/2237/flares-of-fury-poster/

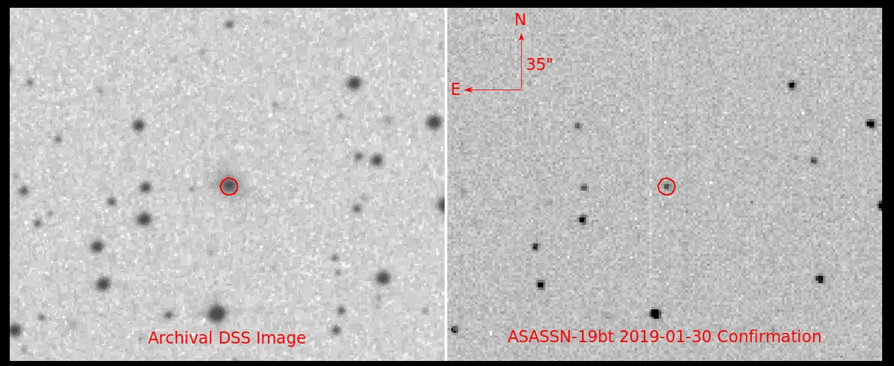
TESS in Exoplanets Research Program (XRP) - Solicitation: NNH20ZDA001N-XRP

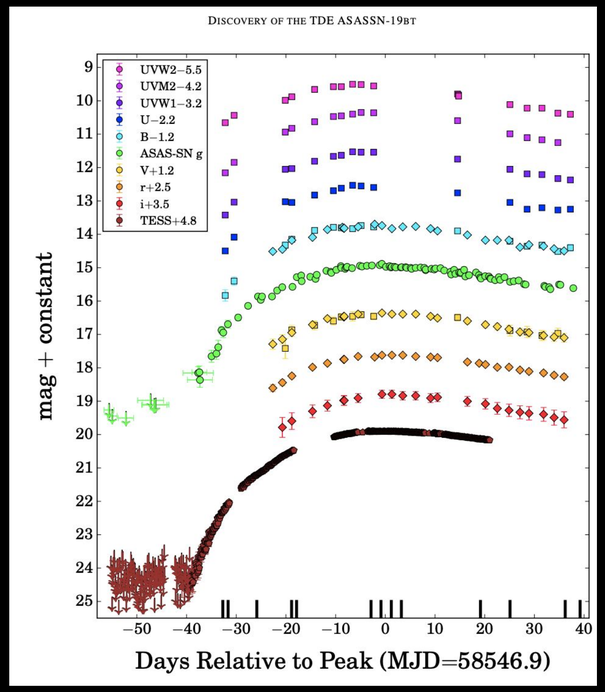
- Step-1 and 2 were due “mid”-pandemic
- 26 XRP proposals selected in total
- 8 proposals directly use TESS data and/or perform investigations of TESS exoplanet systems
- 5 proposals that do not directly use TESS data but mention relevance to the mission
- **This is ~30% of the selections directly using TESS data/discoveries and 50% either using TESS data/discoveries or mentioning relevance to the mission.**

TESS: more than exoplanets!

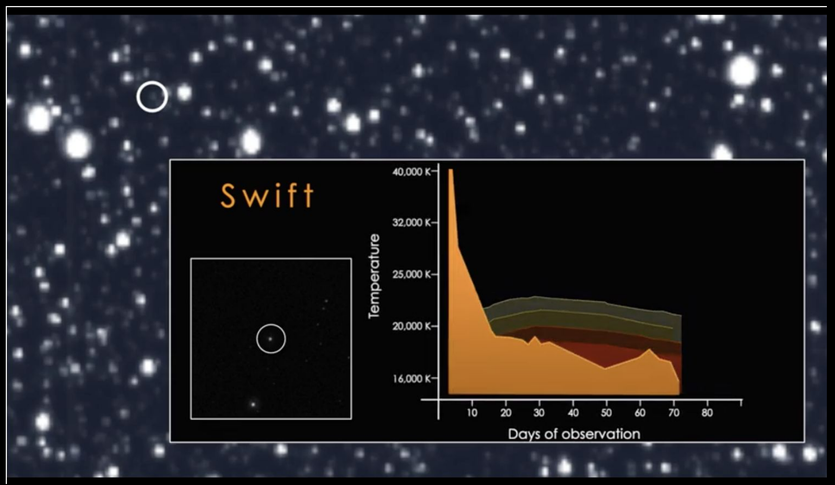


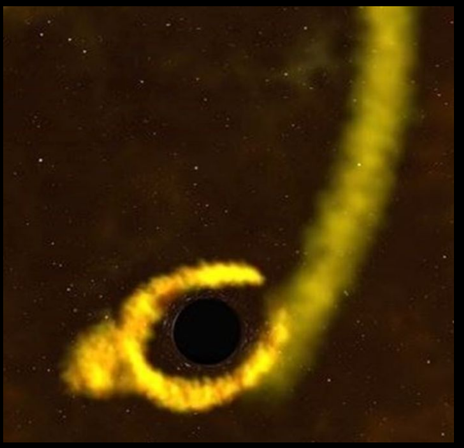
Low-frequency gravity waves in blue supergiants revealed by high-precision space photometry, *Nature Astronomy,* Bowman et al., 2019





Discovery and Early Evolution of ASASSN-19bt, the First TDE Detected by TESS, *ApJ*, Holoien et al ., 2019





Welcome to ExoFOP-TESS

The Exoplanet Follow-up Observing Program for TESS (ExoFOP-TESS) website is designed to optimize resources and facilitate collaboration in follow-up studies of targets observed by TESS, an Explorer-class mission led by MIT. ExoFOP-TESS contains stellar parameters from the TESS Input Catalog (TIC), which is served by the Mikulski Archive for Space Telescopes (MAST), and planet parameters from the NASA Exoplanet Archive.

For information about participating in the TESS Guest Investigator program, please see the TESS Science Support Center.

In order to upload your own data, you must have an account. Users are expected to follow the ExoFOP Professional Conduct Policy.

Please include the following standard acknowledgment in any published material that makes use of ExoFOP: "This research has made use of the Exoplanet Follow-up Observation Program website, which is operated by the California Institute of Technology, under contract with the National Aeronautics and Space Administration under the Exoplanet Exploration Program."

ExoFOP Data Migration

The ExoFOP Archive is in the process of migrating to a single portal. The user uploaded content in the Kepler and K2 portals is being incorporated into the TESS portal. The original user and date of the upload will be retained. As content is migrated, the update feature for that parameter class in the original portal will be disabled. See Status.

TARGETS (TIC V8.1)

NEW Single Target Lookup

Search the TESS Candidate Target List (9,488,282 targets)

Download the TESS Candidate Target List (3.7G)

Follow your favorite targets

TOIS/CTOIS:

List of all TOIs 2,440

List of all CTOIs 1,026

Search TOIs

Includes GI's, community, PlanetHunters

DATA TAGS

Data Tag (e.g. tag number or yyyymmdd_user_description_nnnn):

View all Data Tags for a user (enter username or leave blank to view your own if you are logged in):

OBSERVATIONS

Imaging 13,647

Spectroscopy 13,551

Time Series 4,923

Stellar Companions 3,974

BULK UPLOADS

Files

Observations

Observing Notes

CTOIs/Parameters

Stellar Companions

CHANGE LOG

View the Change Log (last week) 113

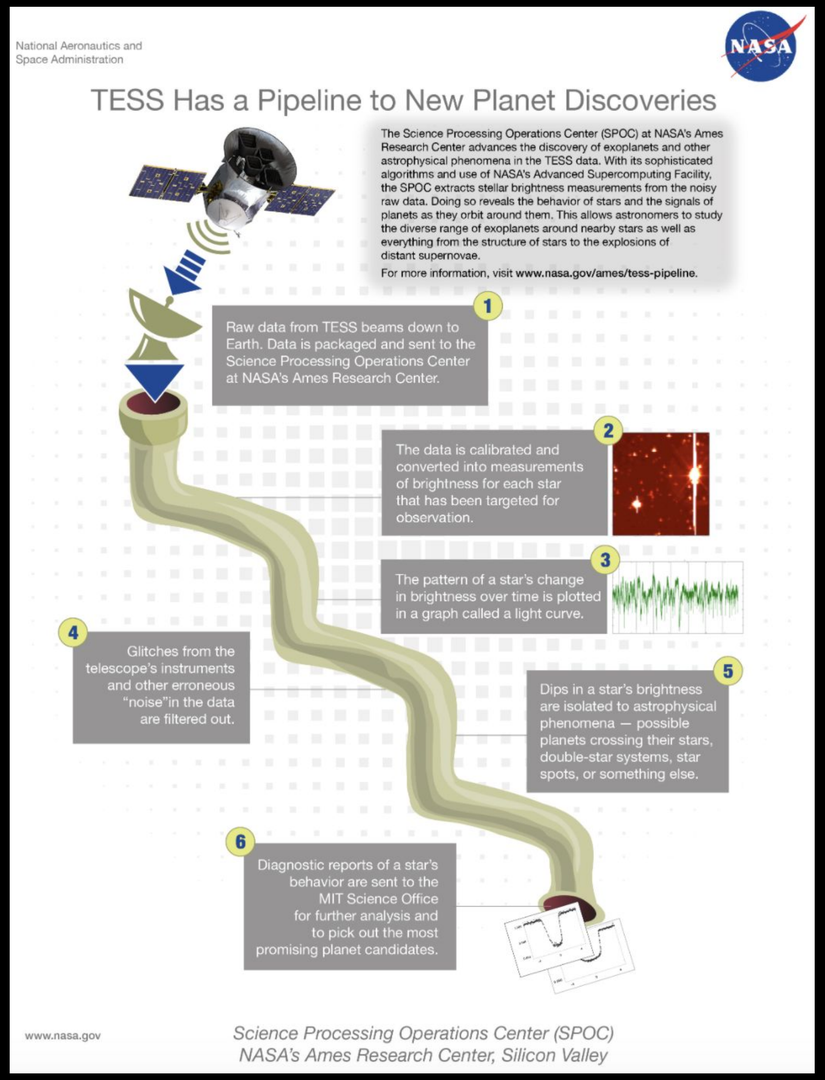
Search the Change Log (all) (enter TICnnn or TOInnn for detailed activity):

Subscribe to the Change Log Summary

https://exofop.ipac.caltech.edu/tess/

Data processing, documentation and archiving

TESS data processed at SPOC/ARC, including multi-sector runs, reviewed with MIT/POC and delivered to MAST @STScI, ahead of schedule



Barbara A. MIKULSKI ARCHIVE FOR SPACE TELESCOPES

MAST | STScI | Tools | Mission Search | Search Website | Follow Us | Register | Forum

TESS Home | Data Products | Search Tools | Documentation | Tutorials

Notice: Around the end of September 2020, archive.stsci.edu will begin using HTTPS exclusively. *read more*

NOTE: Some Sectors have special memos regarding their processing or delivery. If using those Sectors, be sure to check out the PDF linked in the "Memo" next to the DRN links in the table below.

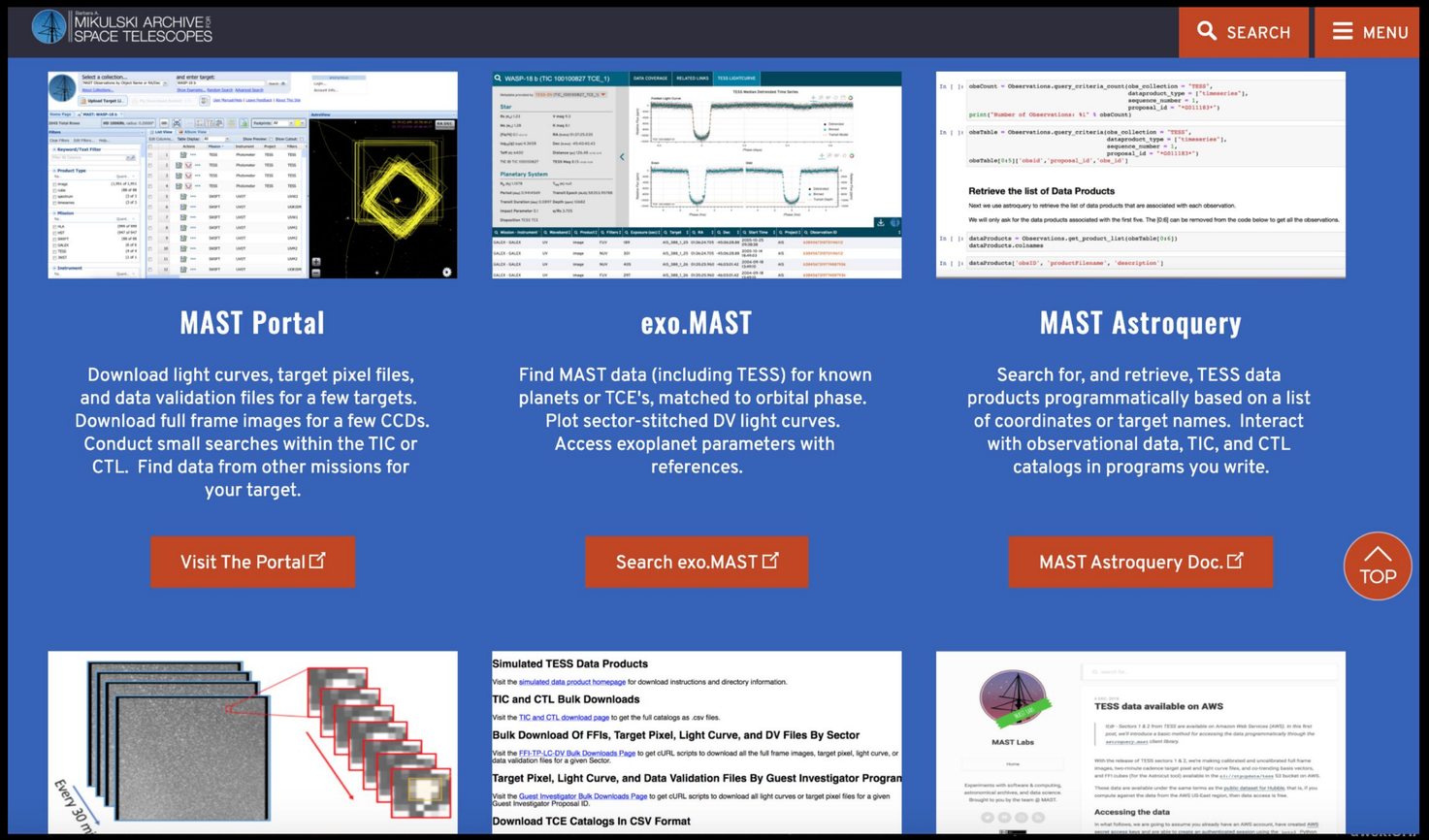
Download all TESS Data Release Notes. The format of the files includes a sector number or range, a data release number ("drn??") that increases with every new Data Release Note and is thus a chronological indicator, and a version number ("v??") in case a given data release note needs to be replaced to fix something.

Note that for multi-sector data release notes, an additional file, called a "target info table", is included in text format. This file contains the set of TESS targets that were searched as part of multi-sector searches, and some additional information on each target's TCE and DV status as part of the run. See the header of the text files for more info.

For your convenience, the start and end times in both UTC and TESS Truncated Julian Date for each orbit in each Sector are provided in this CSV table.

Data Release Notes			
Data Release Number	**Sector(s)**	**PDF File**	**Target Info File (Multisector Only)**
DRN 41	Sector 28	tess_sector_28_drn41_v01.pdf	
DRN 40	Sectors 14-26	tess_multisector_14_26_drn40_v02.pdf	tess_multisector_14_26_drn40_targetinfo_v01.txt
DRN 38	Sector 27	tess_sector_27_drn38_v01.pdf	
DRN 37	Sector 26	tess_sector_26_drn37_v02.pdf	
DRN 36	Sector 25	tess_sector_25_drn36_v02.pdf	

MAST data archive



Data Availability by Sector

Extended Mission (Year 3)

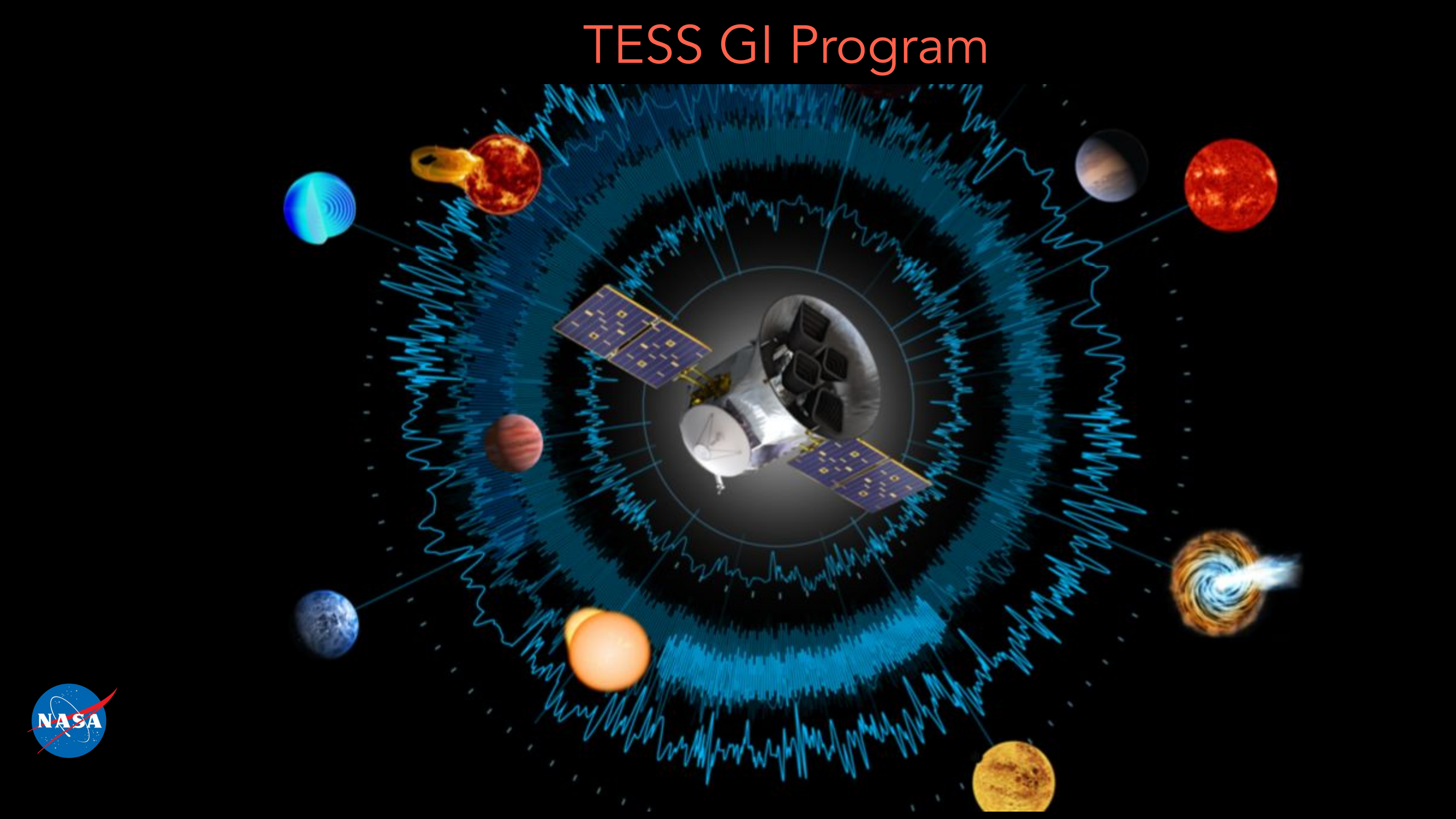
Service/Sector	S27	S28	S29	S30	S31	S32	S33
Data Ingest Started	☑	☑	☑	☑	☑	☐	☐
Portal/Astroquery	☑ FFI ☑ TP/LC/DV	☑ FFI ☑ TP/LC/DV	☑ FFI ☑ TP/LC/DV	☑ FFI ☑ TP/LC/DV	☑ FFI ☑ TP/LC/DV	☐ FFI ☐ TP/LC/DV	☐ FFI ☐ TP/LC/DV
Bulk Downloads	☑ FFI ☑ TP/LC/DV	☑ FFI ☑ TP/LC/DV	☑ FFI ☑ TP/LC/DV	☑ FFI ☑ TP/LC/DV	☑ FFI ☑ TP/LC/DV	☐ FFI ☐ TP/LC/DV	☐ FFI ☐ TP/LC/DV
TESSCut	☑	☑	☑	☑	☑	☐	☐
TCEs available in exo.mast	☑	☑	☑	☐	☐	☐	☐
Data Release Notes	☑	☑	☑	☑	☑	☐	☐
Data available on Amazon Cloud	☑ FFI ☑ TP/LC/DV	☑ FFI ☑ TP/LC/DV	☑ FFI ☑ TP/LC/DV	☑ FFI ☑ TP/LC/DV	☑ FFI ☑ TP/LC/DV	☐ FFI ☐ TP/LC/DV	☐ FFI ☐ TP/LC/DV

Prime Mission (Year 2, Northern Hemisphere)

DR30 refers to the reprocessed data which will replace the original data in the MAST archive.

Service/Sector	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23
Data Ingest Started	☑ orig ☑ DR30	☑ orig ☑ DR30	☑ orig ☑ DR30	☑ orig ☑ DR30	☑ orig ☑ DR30	☑ orig ☑ DR30	☑	☑	☑	☑

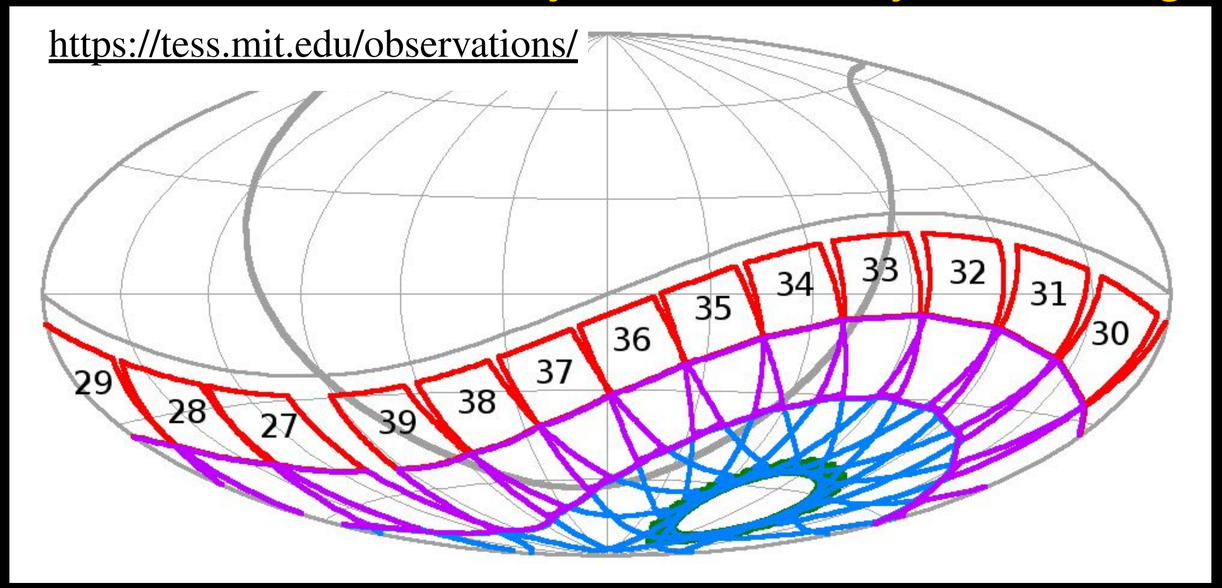
TESS GI Program



TESS Cycle 3 GI Program

- Cycle 3 spans the first year of the Extended Mission (Sectors 27-39 i.e. July 4, 2020 - June 24, 2021)
- Pointings cover the Southern Ecliptic hemisphere
- New 20-second cadence mode with ~600 target slots available to the community per sector
- An 8x increase in the number of 2-minute cadence targets available to the GI program with >12,000 target slots per sector

The TESS Cycle 3 peer review transitioned from in-person to a fully virtual review with just weeks to replan, and we are indebted to the NASA and NRESS support staff as well as all our reviewers across multiple time zones and locations for their flexibility and resiliency for making this a smooth transition.



TESS Cycle 3 GI Program

- >$3M awarded to US investigators programs to analyze 10-minute (FFI), 2-minute, or 20-second cadence data or for ground-based observing programs that will support the interpretation of TESS data.
- PSD funded a highly-ranked solar system key project.
- Selected programs include:
  - Large and Small programs FFI, 2-min, and/or 20-sec data
  - Key Projects (with max duration of 27 months)
  - Ground-based observing programs
  - Joint TESS-Swift programs
  - Joint HST-TESS program (through HST Cycle 28)

https://heasarc.gsfc.nasa.gov/docs/tess/approved-programs.html

Slide from K. Colón (NASA Goddard)

TESS Cycle 4 GI Program

- Proposal deadline anticipated 22 January 2021; call out in late October 2020
- Cycle 4 observations expected to start in June 2021 and to span 16 sectors
- Pointings will cover the Northern Ecliptic hemisphere and part of the Ecliptic plane (including revisits of some K2 Campaign FOVs)
- Proposals for 2-minute and 20-second cadence targets and for funding to support the analysis of new 2-minute, 20-second, and FFI data are solicited
- Ground-based focused programs that support the analysis of TESS data are solicited
- Joint programs with Swift solicited (for up to 100 ks of Swift time)
- Joint programs with HST solicited (through the HST Cycle 29 call)
- Joint programs with Fermi solicited (through the Fermi Cycle 14 call)

Slide from K. Colón (NASA Goddard)

Changes from Cycle 3

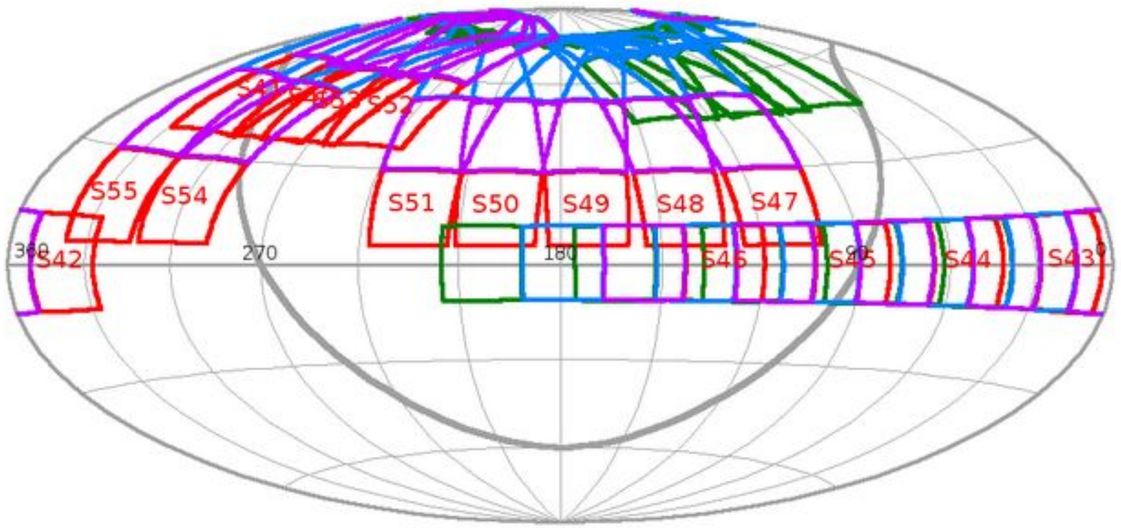
- Proposals will be dual-anonymous
- Total funding awarded will be increased compared to previous cycles since Cycle 4 (16 sectors) is longer than previous cycles (13 sectors each)
- Soliciting short ”mini” proposals for small numbers of targets (and no funding)
- Joint programs with Fermi solicited (through the Fermi call)
- Key Project proposals will not be solicited (since Cycle 4 is end of EM1)

Slide from K. Colón (NASA Goddard)

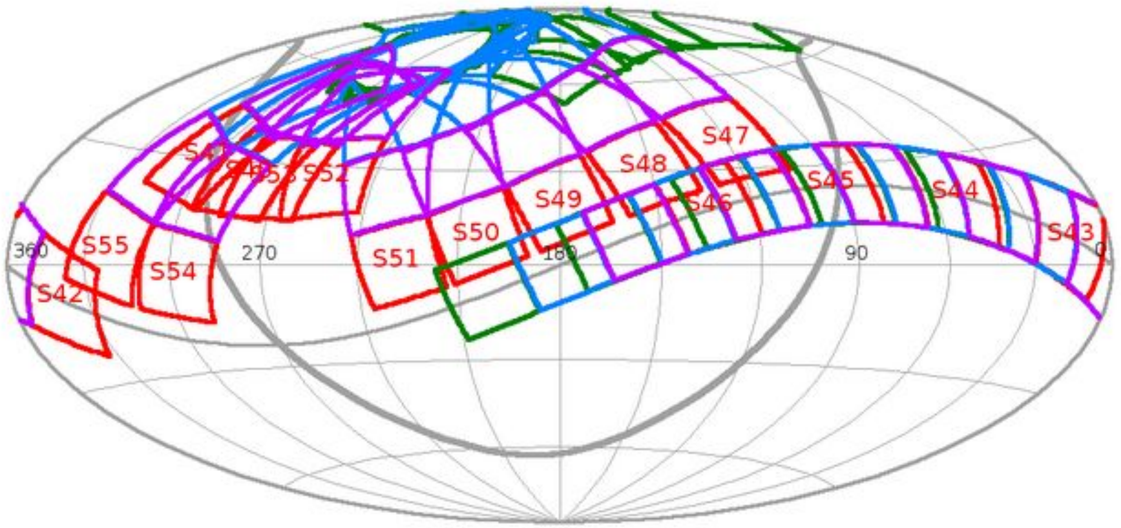
Plan for Cycle 4 (15 months) finalized

Sector numbers:

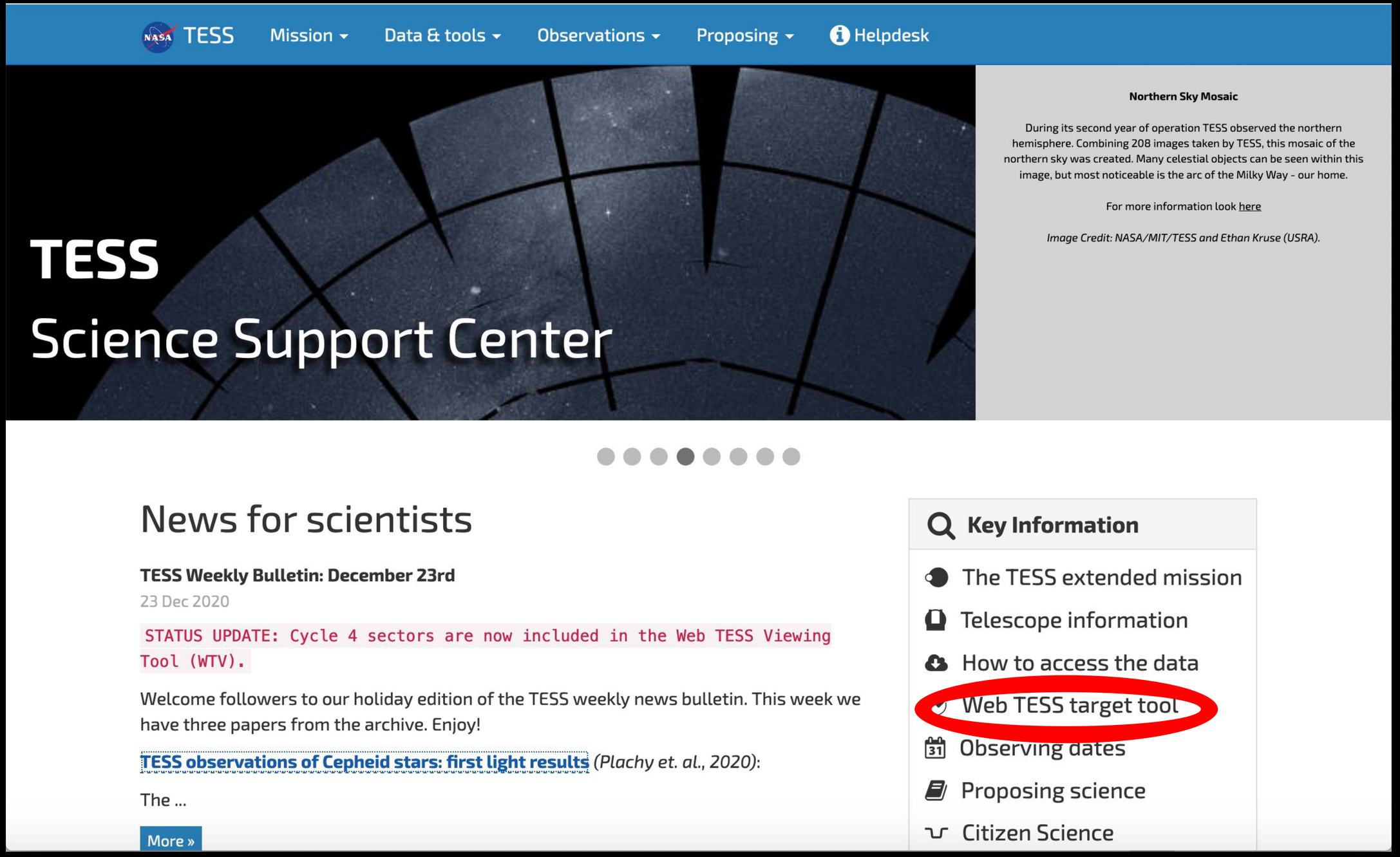
40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
N	N	E	E	E	E	E	N	N	N	N	N	N	N	N	N
7/21															9/22



Cycle 4 fields in Ecliptic coordinates



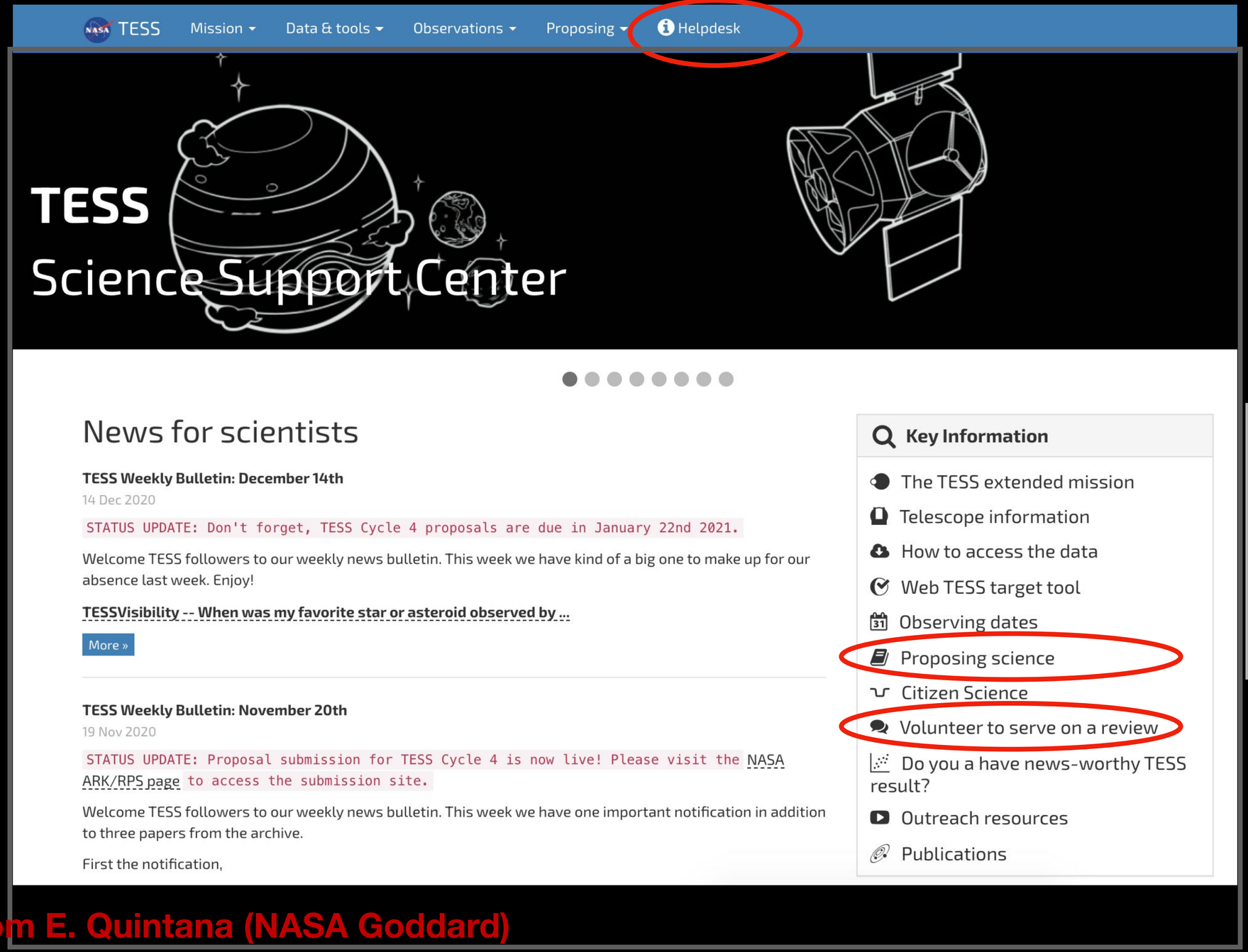
Cycle 4 fields in Celestial coordinates



tess.gsfc.nasa.gov

Cycle 4 Guest Investigator Proposals due 1/22/21

tess.gsfc.nasa.gov



*New joint HST, Fermi, and Swift programs

Write a proposal!

(or consider volunteering to serve on a review)

Slide from E. Quintana (NASA Goddard)

Lightkurve

Adding more TESS tutorials and making sure lightkurve is compatible with 20-second cadence data

A friendly package for Kepler & TESS time series analysis in Python.

Quickstart →

Time domain astronomy made easy for all

Lightkurve offers a user-friendly way to analyze time series data obtained by telescopes, in particular NASA's Kepler and TESS exoplanet missions.

Lightkurve aims to lower barriers, promote best practices, reduce costs, and improve scientific fidelity by providing accessible Python tools and tutorials.

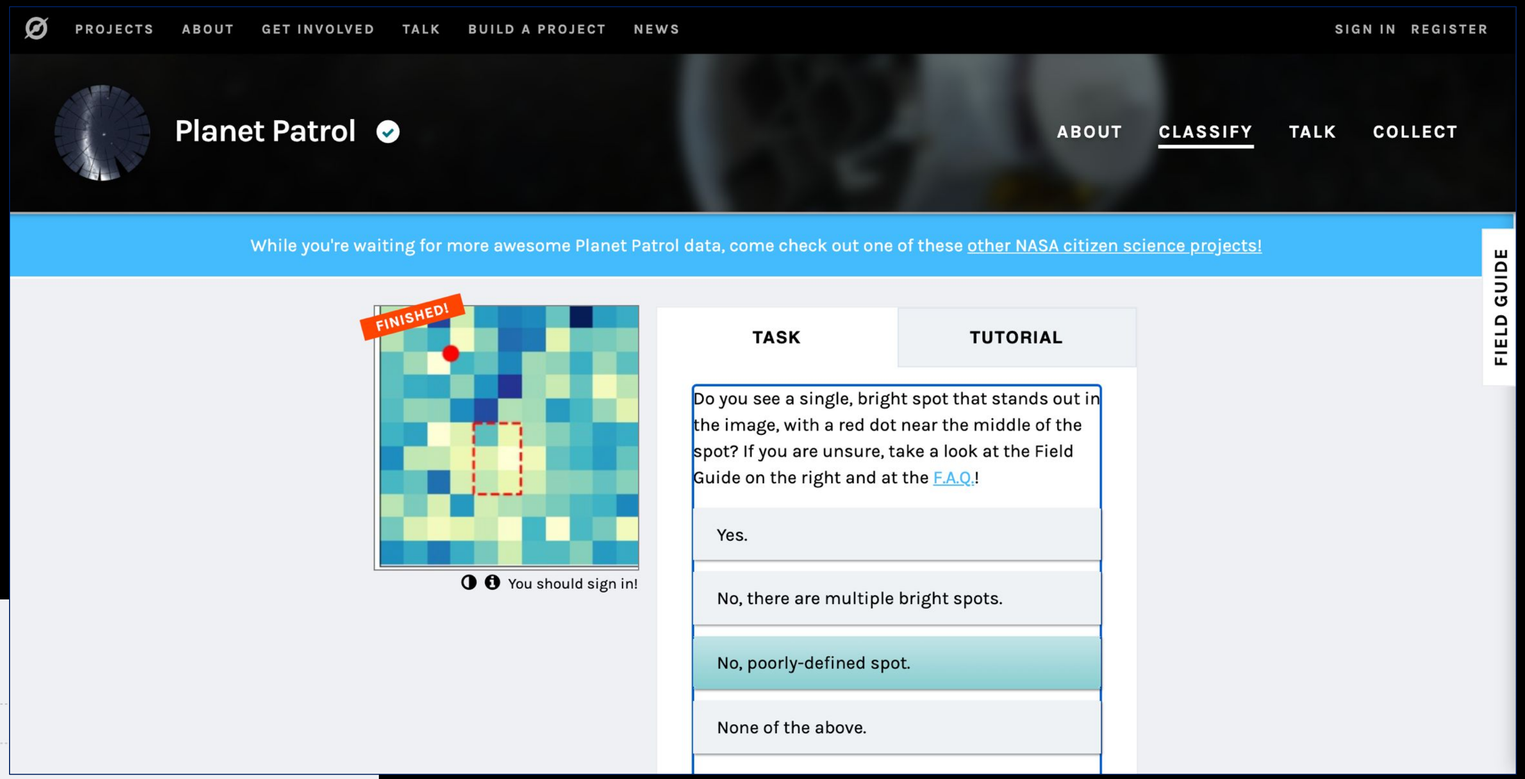
```
import lightkurve as lk

pixels = lk.search_targetpixelfile("Kepler-10").download()
pixels.plot()

lightcurve = pixels.to_lightcurve()
lightcurve.plot()

exoplanet = lightcurve.flatten().fold(period=0.838)
exoplanet.plot()
```

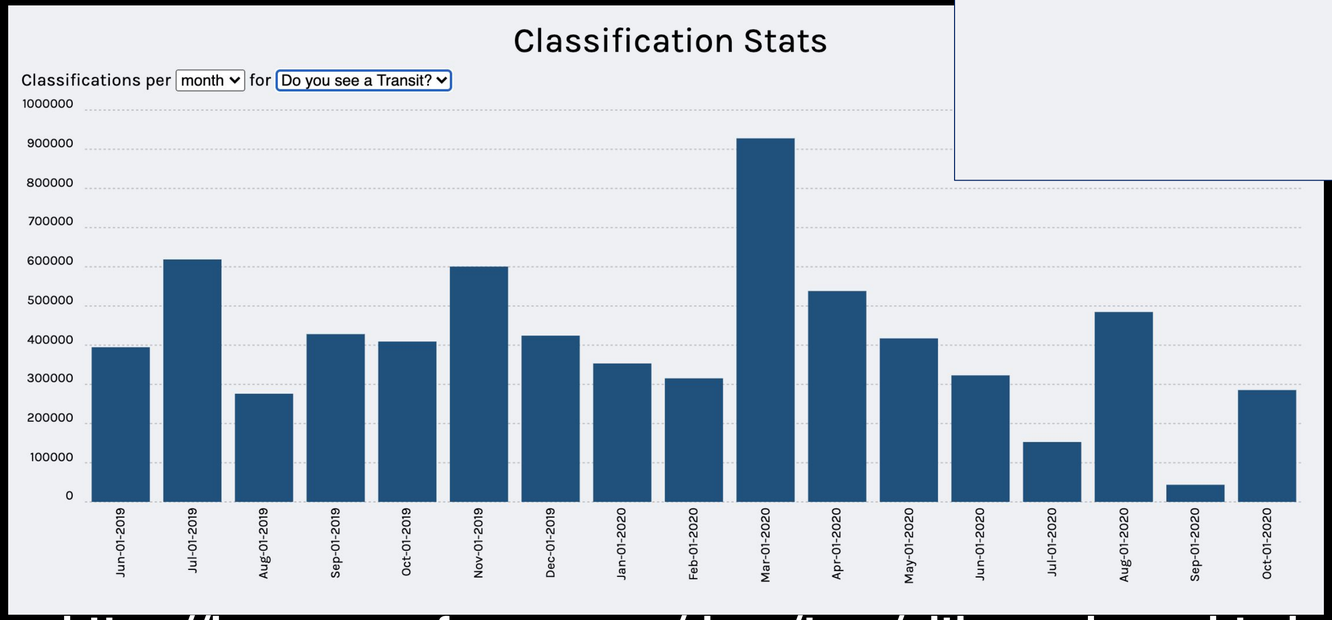
Slide from K. Colón (NASA Goddard)

https://docs.lightkurve.org/

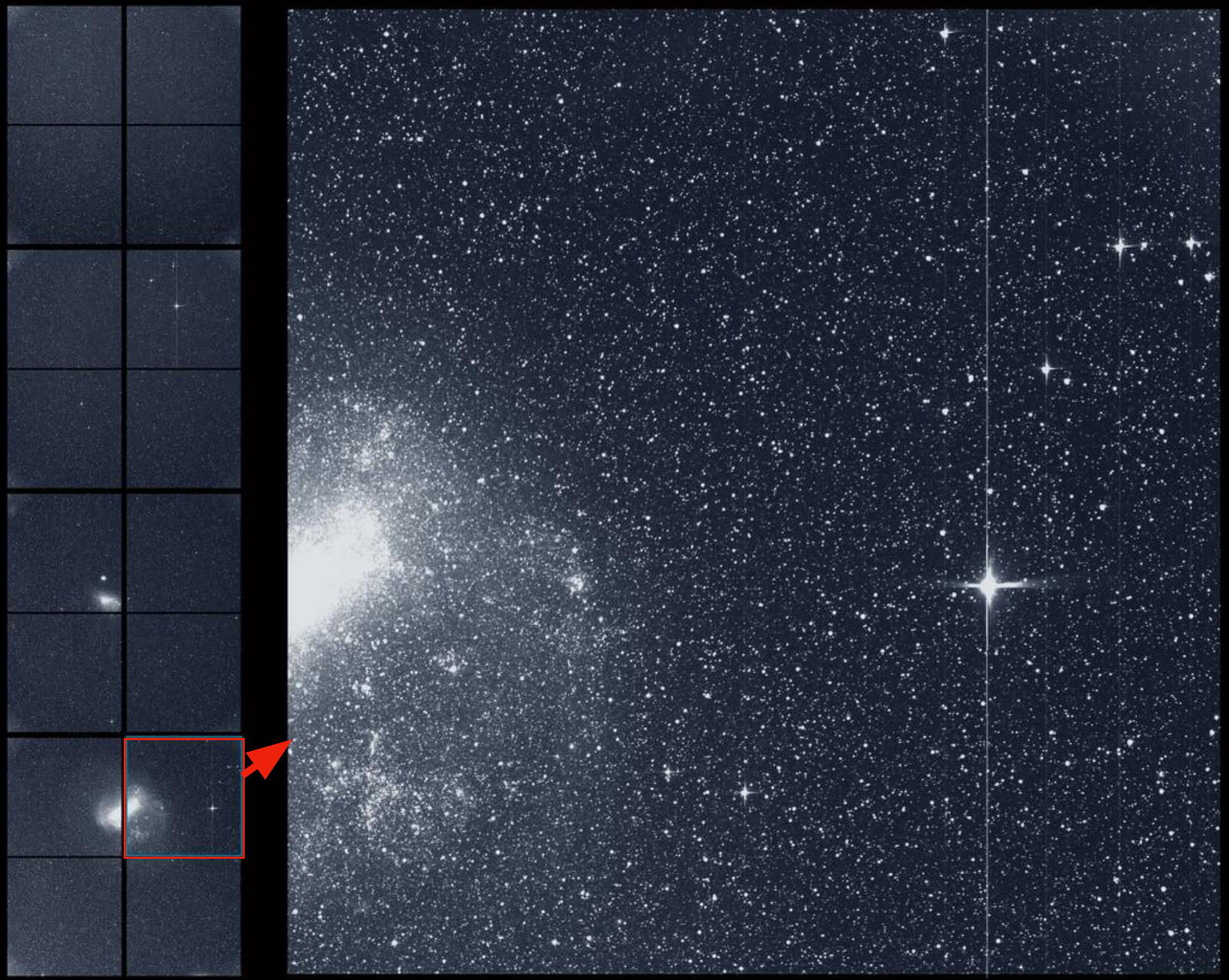
TESS Citizen Science

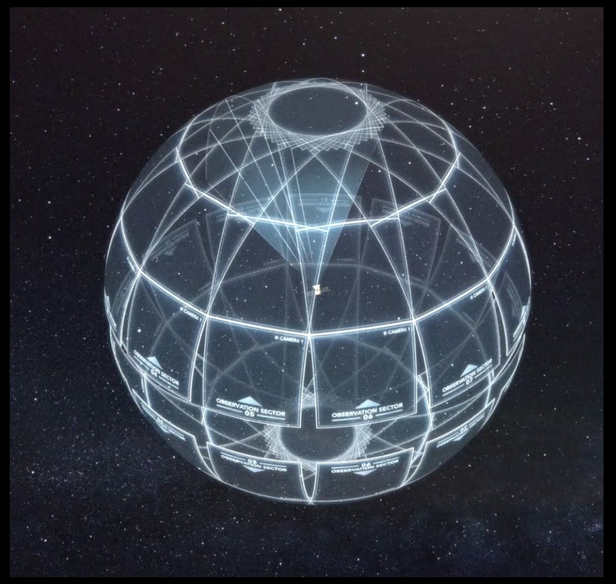
Planet Hunters TESS





https://heasarc.gsfc.nasa.gov/docs/tess/citizenscience.html

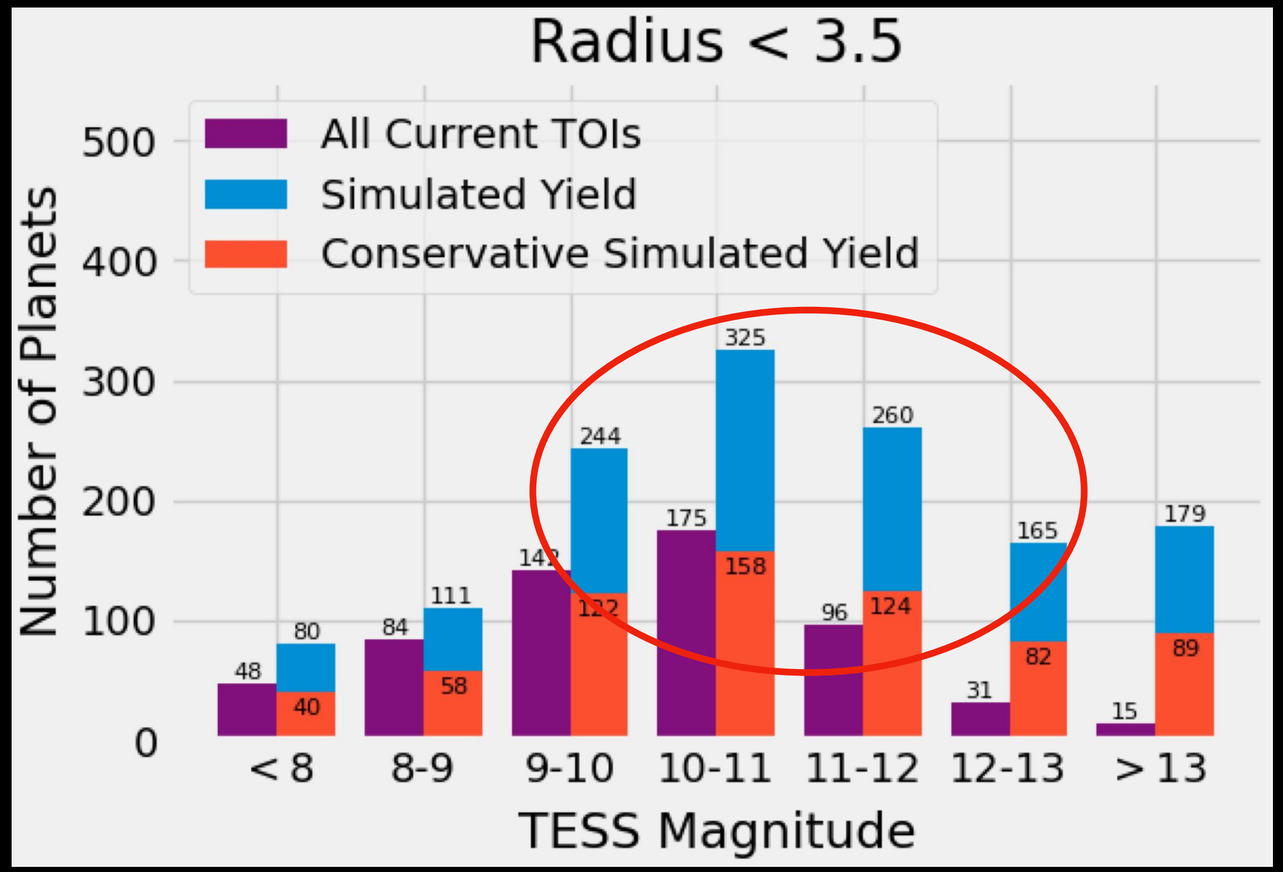


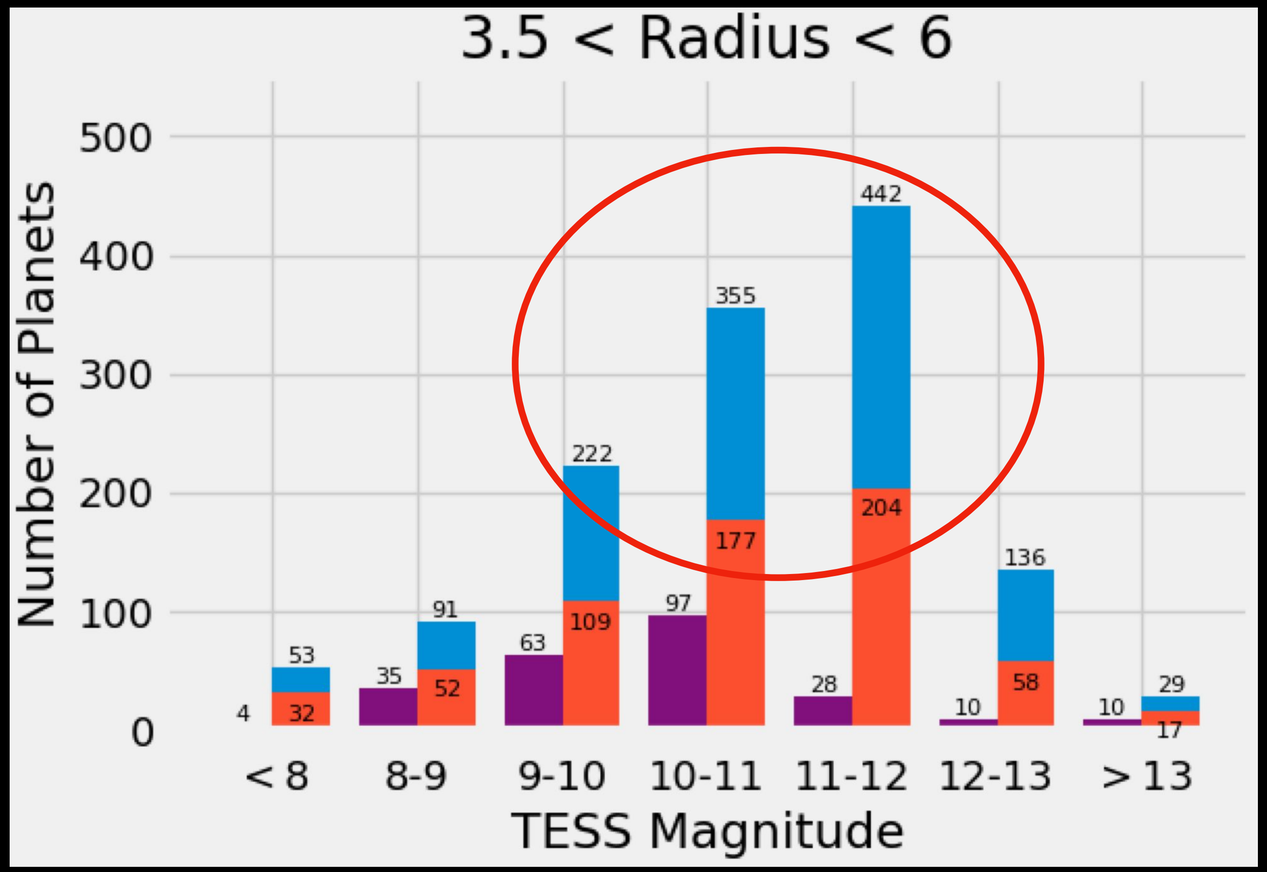


In each “Sector”, over 3M stars brighter than mag 15

TESS Mag	Number of Targets	Cumulative Targets
< 8	6,789	6,789
8–9	12,107	18,896
9–10	31,053	49,949
10–11	74,038	123,987
11–12	168,640	292,627
12–13	369,272	661,899
13–14	779,478	1,441,377
14–15	1,592,905	3,034,282

Small Planets vs TESS Magnitude





predictions including FFIs, by Barclay et al. 2019 ; Hundreds of sub-Neptunes and Neptunes around bright stars awaiting discovery (potential JWST/ARIEL targets)!

Enabling science from FFI Light Curves:

- FFI light curves from TESS Project (Ames/SPOC & MIT/QLP & TICA) available or soon to be available on MAST
- FFI light curves from community and GI teams (eg. *eleanor* team) (PI Montet) either on MAST now or expected soon for Prime Mission
- GSFC intends to generate and deliver *eleanor* FFI light curves to MAST for stars brighter than 15th magnitude for extended mission
- Treasure trove of science awaits within “gold mine” of data in FFIs (transients, AGN, supernova, +)

AAS Special Session: “Mining TESS Data with Machine Learning and Other Advanced Methods”

Thurs Jan 14 (12-1:30 ET)

Slide from E. Quintana (NASA Goddard)

Summary and Coming up next…

- TESS data holdings at MAST remain popular with the science community, and are growing
- GI Program continues to be very popular in areas from solar system to extragalactic objects in addition to exoplanets
- Extended Mission now well underway. New data modes working well and getting nice sci.
- TESS key science results receive high visibility in online news sites and social media
- Citizen science projects are engaging broader community
- All spacecraft and ground systems remain healthy, and we look forward to many more years of exciting science enabled by TESS, in this extended mission and beyond.
- Check out 2 TESS special sessions, a “TESS Tools and Tutorials” Webinar, and 3 press conferences at AAS! Our annual “Evening Splinter Session” is postponed until we can all be in person again, hopefully next AAS!

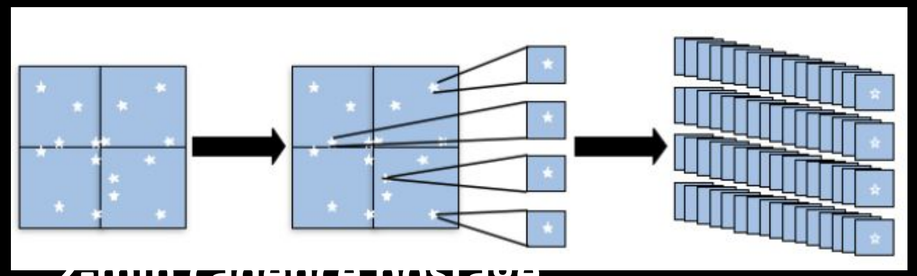

CH_4 (methane)
Land-Covered
Modern Earth
NEOWISE Comet
L 98-59b
Earth
L 98-59d
Pi Mensae
Star
Mass: 1.1 solar masses
Brightness: 1.4 solar
Temperature: 10,400 F
TOI 270
System
Earth
TOI 270 c
TOI 270
TOI 270 b
KEPLER SEARCH AREA
3000 LIGHT YEARS
https://asd.gsfc.nasa.gov/media_req_tess/

TESS Data Modes

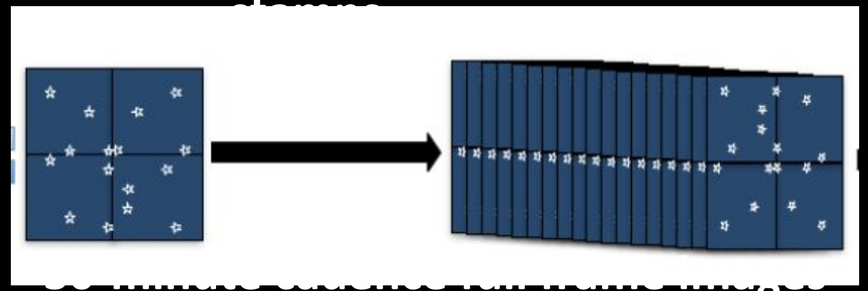
TESS Prime Mission (July 2018-July 2020)

Yr 1: southern hemisphere

Yr 2: northern hemisphere



2-min cadence postage stamps

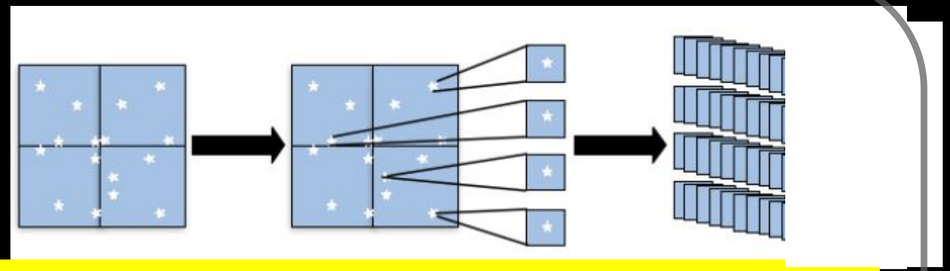


30-minute cadence full frame images (FFIs)

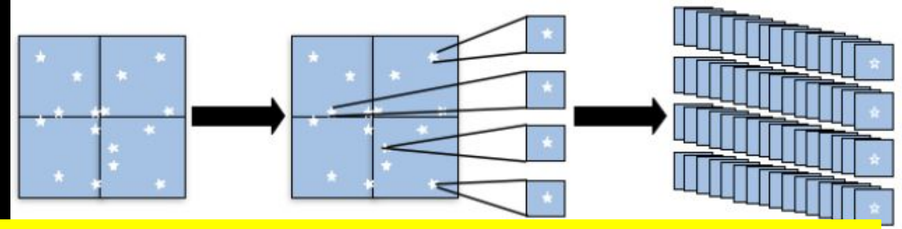
TESS Extended Mission (July 2020 –Sept 2022)

Yr 3: southern hemisphere

Yr 4: northern hemisphere + ecliptic



20-second cadence ~1000 targets per sector



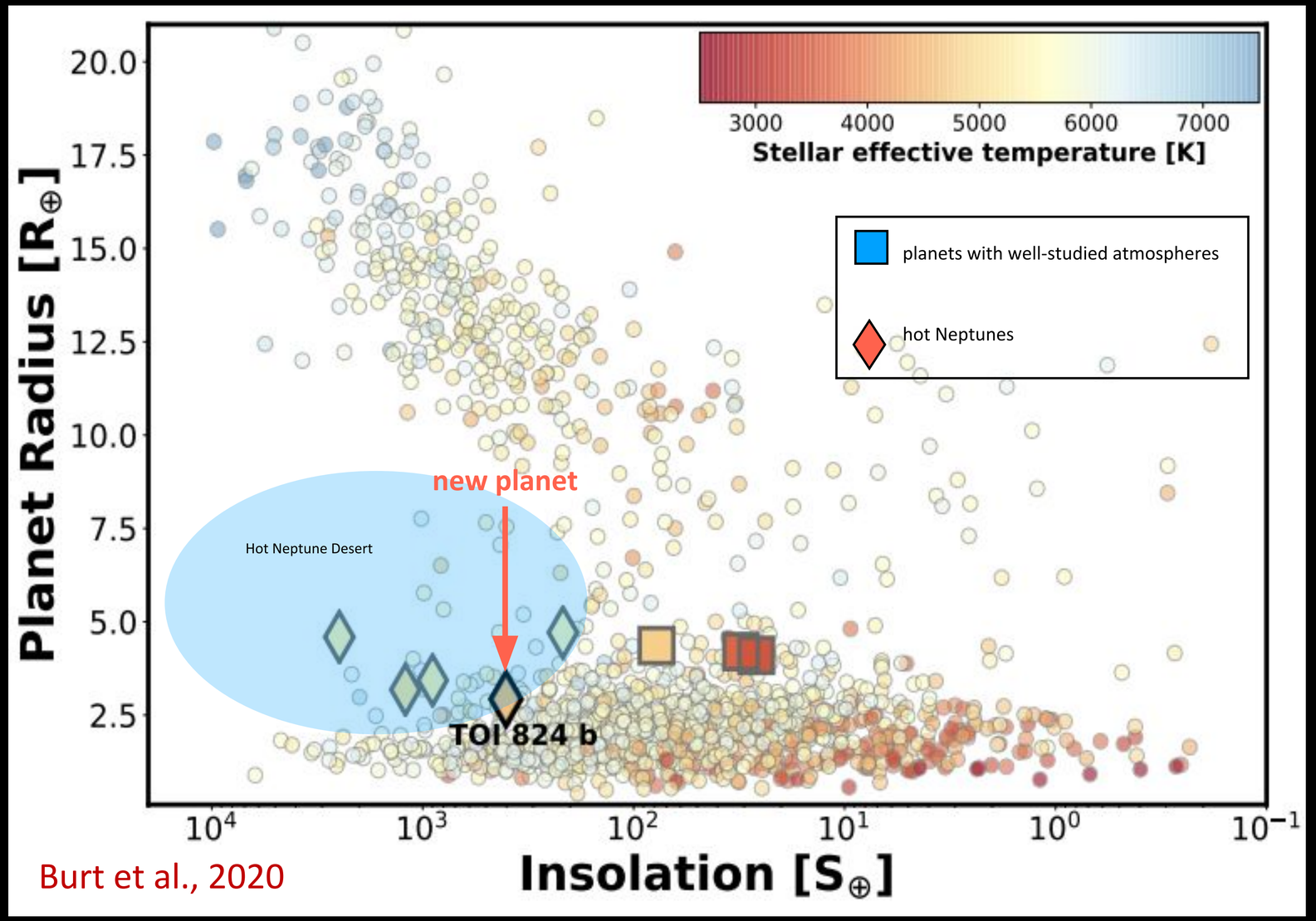
2-min cadence ~15,000 targets in each sector

10-minute cadence FFIs

Mission products archived @MAST:

Light curves for 2min (+20 sec) from Ames SPOC; calibrated FFIs only (no light curves)

A New Planet on the Lower Edge of the Hot Neptune Desert: TOI-824 b



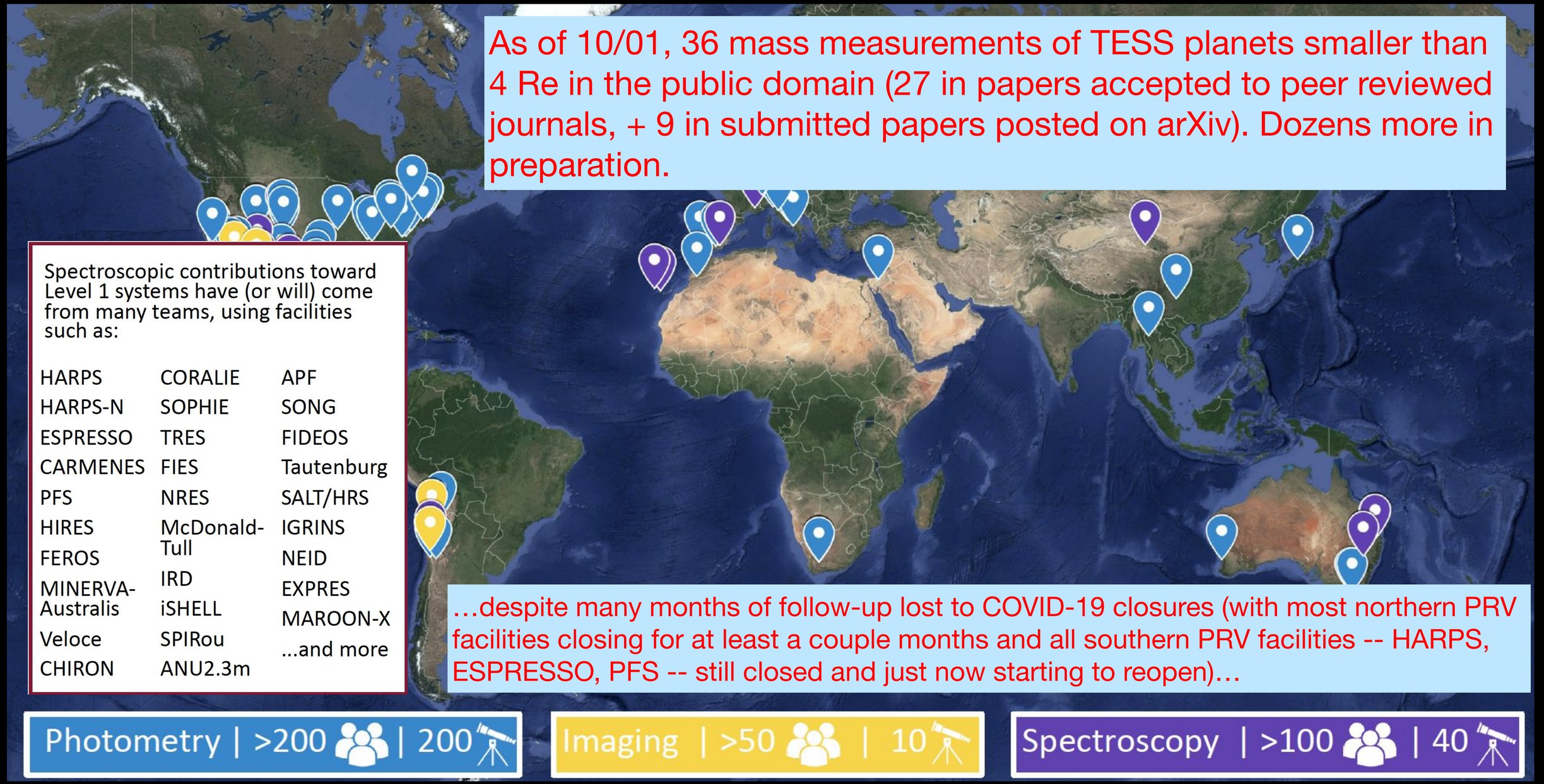
Burt et al., 2020

The “hot Neptune desert” refers to the dearth of planets the size and mass of Neptune on periods shorter than 4 days

TOI-824 b has a precise mass and likely a cloud-free atmosphere, making it a promising target for the detection of atmospheric escape

“The detectability of TOI-824 b's atmosphere from both ground and space is promising and could lead to the detailed characterization of the most irradiated, small planet at the edge of the hot Neptune desert that has retained its atmosphere to date.” Burt et al., 2020, AJ 160:153

TESS Follow-Up Observing Program (TFOP) – graphic credit Sam Quinn (SAO)



As of 10/01, 36 mass measurements of TESS planets smaller than 4 Re in the public domain (27 in papers accepted to peer reviewed journals, + 9 in submitted papers posted on arXiv). Dozens more in preparation.

Spectroscopic contributions toward Level 1 systems have (or will) come from many teams, using facilities such as:

HARPS	CORALIE	APF
HARPS-N	SOPHIE	SONG
ESPRESSO	TRES	FIDEOS
CARMENES	FIES	Tautenburg
PFS	NRES	SALT/HRS
HIRES	McDonald-Tull	IGRINS
FEROS	IRD	NEID
MINERVA-Australis	iSHELL	EXPRES
Veloce	SPIRou	MAROON-X
CHIRON	ANU2.3m	...and more

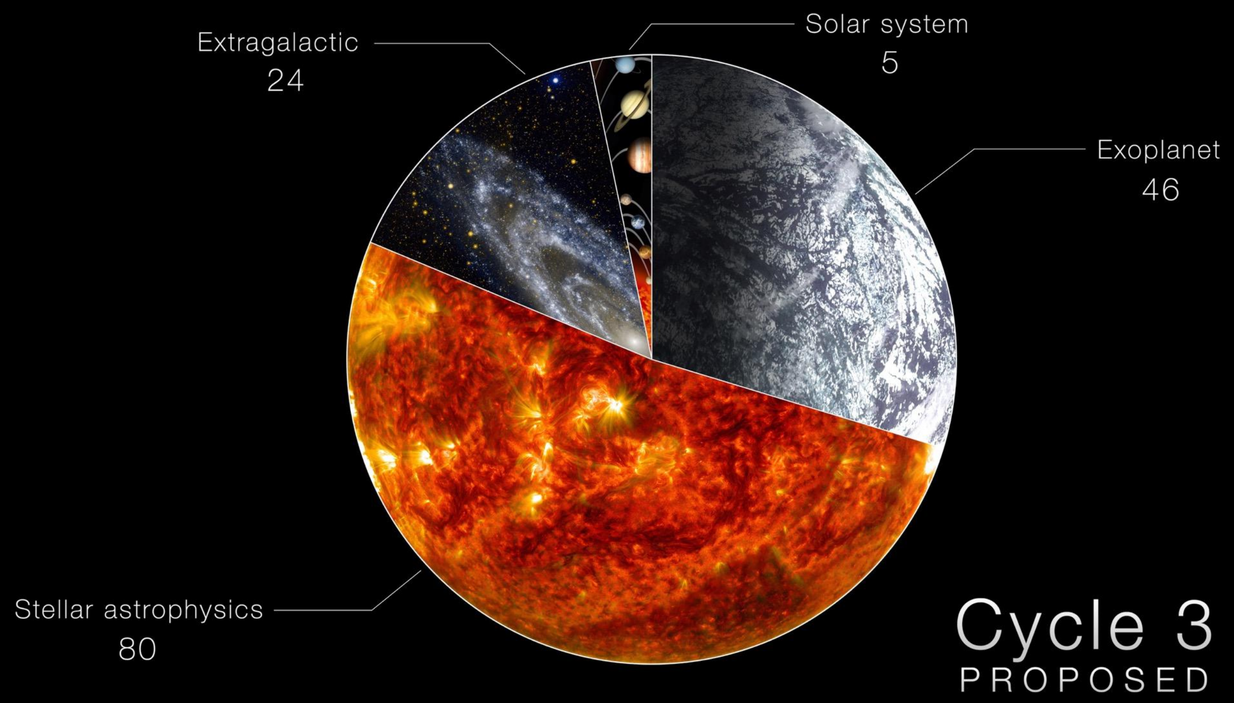
…despite many months of follow-up lost to COVID-19 closures (with most northern PRV facilities closing for at least a couple months and all southern PRV facilities -- HARPS, ESPRESSO, PFS -- still closed and just now starting to reopen)…

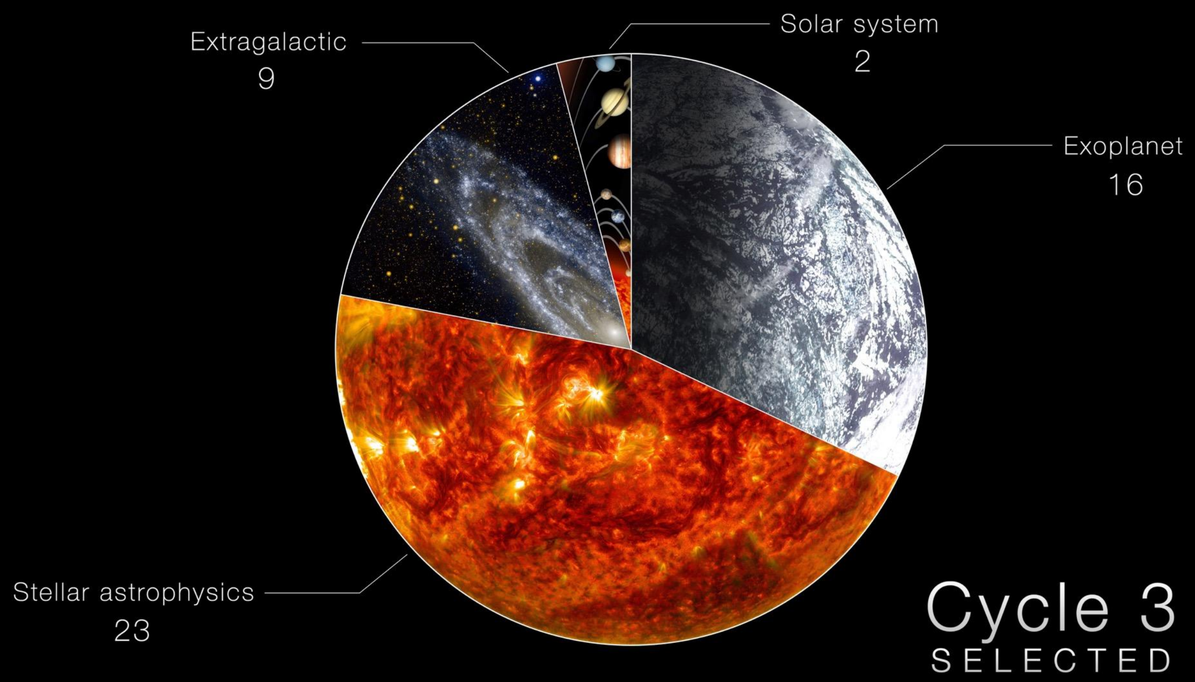
Photometry | >200 | 200

Imaging | >50 | 10

Spectroscopy | >100 | 40

GI Program-Extended Mission





TESS Cycle 3 GI Selected Joint Swift-TESS Projects

- Vega, Laura: Exploring The Star-Planet Connection Via Simultaneous TESS And Swift Observations Of Highly Active M Dwarfs
- Jorstad, Svetlana: TESS Observations Of Gamma-Ray Blazars
- Coley, Joel: Probing The Radiative Losses In The High-Mass Gamma-Ray Binary Psr B1259-63 With TESS, Swift And Fermi

Slide from K. Colón (NASA Goddard)

Other FFI Light Curve Resources

Resource	Lead by	Sectors/Magnitudes	Notes
TESS Asteroseismic Science Consortium	TASC	FFI light curves for TESS Sectors 1-2, down to ~13th mag.	On MAST (HLSP) Tailored to astroseismology applications
Cluster Difference Imaging Photometric Survey (CDIPS)	PI Luke Bouma (Princeton) •Bouma et al. 2019	FFI light curves for 160k stars in Sectors 6-7; 356k stars in Sectors 8-11 for stars brighter than Gaia Rp mag >16	On MAST (HLSP) Tailored for stars that are candidate members of open clusters and moving groups
eleanor: FFI pipeline	PI Ben Montet (UNSW Australia)/Jacob Bean (U Chicago) •Feinstein et al. 2020	open-source tool for extracting light curves from the TESS FFIs.	Expected to be delivered to MAST
Delta Function Difference Imaging Pipeline	PI Ryan Oelkers/Keivan Stassun (Vanderbilt) •Oelkers & Stassun 2019	FFI light curves for Sectors 1-5 down to ~14th mag; Open-source pipeline available on GitHub.	Available on TESS Filtergraph portal (staged at Vanderbilt)

MAST Hosts TESS High Level Science Products
Example- CDIPS. Others available. More coming soon!

CDIPS: DR4 (Bouma et al.)

http://archive.stsci.edu/hlsp/cdips

Cluster Difference Imaging Photometric Survey

- Light curves from FFIs of targets that are candidate members of open clusters, moving groups, or otherwise show evidence of youth.
- Latest release, DR4, contains 26,956 light curves from Sectors 1-5. This release also completes the Southern Hemisphere with CDIPS light curves now available for Sectors 1-13.
- Also included for the first time: a catalog of target metadata, including Gaia parallax and magnitude values, along with cluster membership provenances.
- DR4 is public online now, bulk scripts work, Portal and astroquery updates will be done soon. Look for announcement on MAST social.

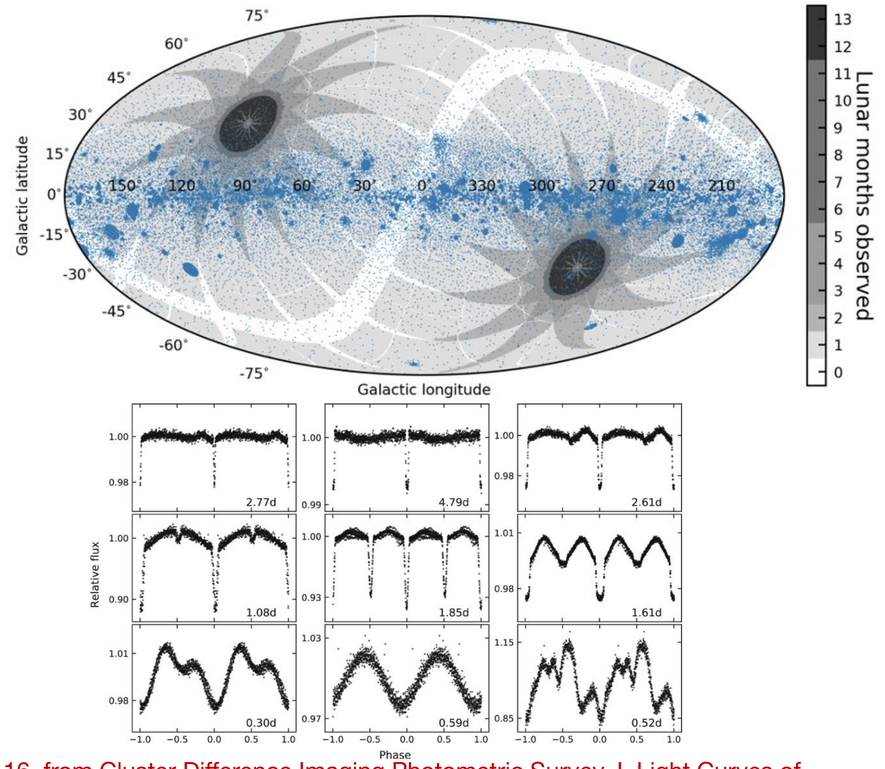


Figure 16. from Cluster Difference Imaging Photometric Survey. I. Light Curves of Stars in Open Clusters from TESS Sectors 6 and 7
2019 APJS 245 13 doi:10.3847/1538-4365/ab4a7e
http://dx.doi.org/10.3847/1538-4365/ab4a7e

STScI | SPACE TELESCOPE SCIENCE INSTITUTE

Slide from S. Fleming (STScI/MAST)

New on MAST: FFI Light Curves as High-Level Science Products

https://archive.stsci.edu/tess/tess_hlsp

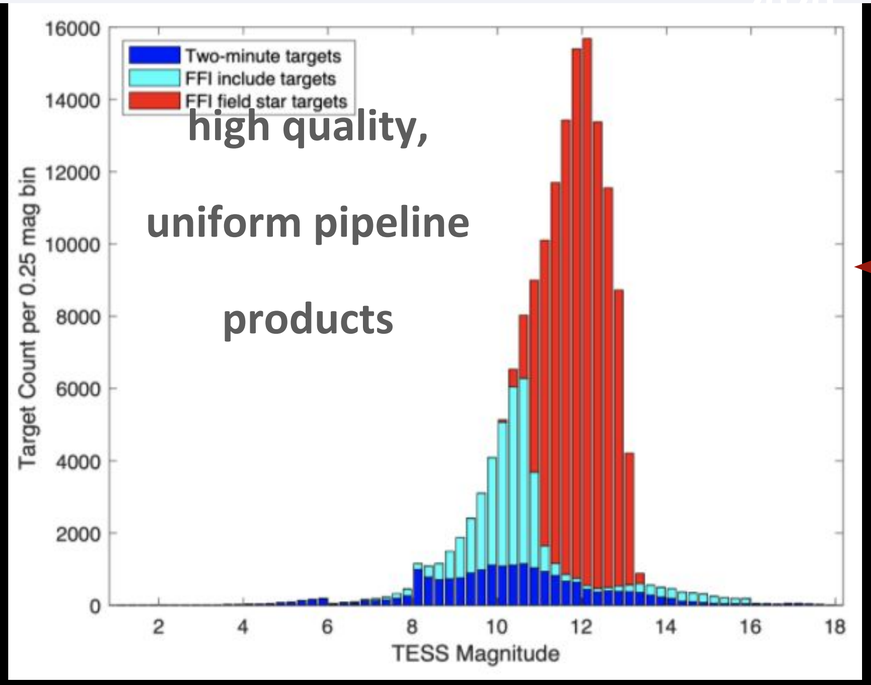
TESS Light Curves From Full Frame Images ("TESS-SPOC")

Primary Investigator: Douglas A. Caldwell

HLSP Authors: Douglas A. Caldwell, Jon M. Jenkins, Eric B. Ting, Peter Tenenbaum, Joseph D. Twicken, Jeffrey C. Smith, Christina Hedges, Michael M. Fausnaugh, Christopher J. Burke, Bill Wohler

Released: 2020-11-12

Caldwell et al. 2020



high quality,

uniform pipeline

products

160k stars per sector (~10k/ccd)

10M stars Tmag < 13

TESS Lightcurves From The MIT Quick-Look Pipeline ("QLP")

Primary Investigator: Chelsea X. Huang

HLSP Authors:

Sector 1 onwards: Chelsea X. Huang, Andrew Vanderburg, András Pál, Lizhou Sha, Liang Yu, Willie Fong, Michael Fausnaugh, Avi Shporer, Natalia Guerrero, Roland Vanderspek, George Ricker

Sectors 27 onwards: Michelle Kunimoto, Willie Fong, Evan Tey, Avi Shporer, Natalia Guerrero, Michael Fausnaugh, Roland Vanderspek, George Ricker

Released: 2020-11-12

Huang et al. 2020a,b