**EXPANDING THE FRONTIERS OF SPACE ASTRONOMY**

"TESS Data Workshop"
(Doing science with TESS)

2019 Feb 11-14

Context

- TESS is an MIT-led NASA mission that will obtain precise photometry for 200k stars with 2 minute cadence and full-frame images with 30 minute cadence.

- TESS will observe 85% of the sky (excluding the ecliptic) in 26 overlapping sectors, each for 27 days.

- TESS will study exoplanets, stellar interiors, stellar binaries, variable stars, AGN, and supernovae.

- MAST will serve TESS data products (full frame images, target pixel files, extracted light curves) to the community.

- MAST will provide a Discovery Portal, a web-based interface for SQL queries, bulk downloads, FFI time series cutout tool.
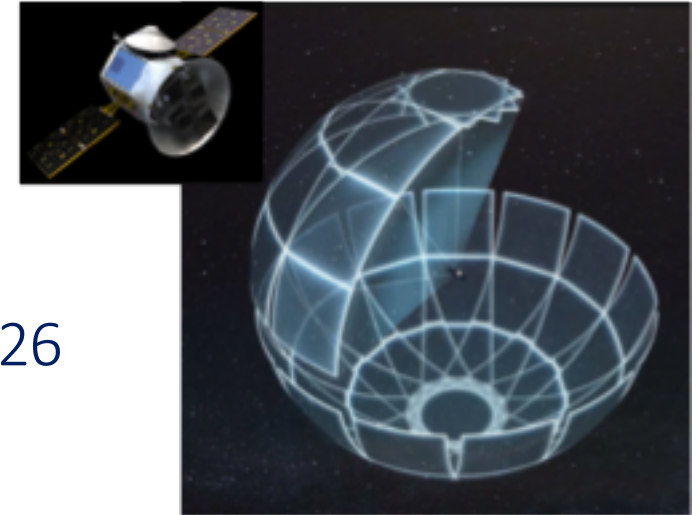
Popular Data Products

Product	Description	Script Examples
ETE-6	Simulated TESS Data Products.	ETE-6 Homepage
*ffic.fits.gz	Calibrated Full Frame Images.	IDL, Python
*tp.fits.gz	Target Pixel Files.	IDL, Python
*lc.fits.gz	Extracted light curves.	IDL, Python

Search and Tools

Discovery Portal	CasJobs	Bulk Downloads
Cross-mission search across all MAST missions and the Virtual Observatory. Upload source lists, spatial cross-match with MAST, VO, and catalogs. Interactive spectral and light curve plotting, charts, image cutouts, and footprint overlay. Advanced search enables pre-filtering on metadata.	Web-based interface for SQL queries to MAST data and catalog tables. Upload your own tables, download results in FITS or CSV format. Quick run for queries that take less than a minute, can also submit long queries for retrieval later. Results and queries are saved for re-use at any time.	For users who want to download files in bulk, we offer programmatic access and links to TESS files. Visit the Bulk Downloads page for information and access.

Workshop timing

- <u>Dec 2018</u> – Planned public release of the first 4 sectors of TESS data (~13% of the sky). One more sector will be released each month thereafter.

- **<u>2019 Feb 11-14</u> – Proposed date for TESS data workshop at STScI.** This will be soon after the first public data release and will be before the first TESS science conference.

- <u>2019 Mar 4-8</u> – K2 conference at Caltech, celebrating 10 years since launch of Kepler.

- <u>2019 Jul 29 to Aug 2</u> – MIT will host "the first <u>conference</u> dedicated to TESS mission science".

STScI scheduling constraints

- STScI calendar
  - 2018 July 9 – Science staff meeting (workshop selection)
  - **2019 Feb 11-14 – Proposed TESS Data Workshop** *[7 months away]*
  - 2019 Mar 25-27 – Hubble Fellows Symposium
  - 2019 Apr 22-26 – Spring Symposium

- Event planning constraints
  - Start event planning at least 8 months before event
  - Leave a gap of at least 3 weeks between major events (including workshops)
  - Registration closes 30 days before workshop [Jan 11, immediately after AAS meeting]

Workshop goals

- In a nutshell: **Start doing science with TESS data**

- Educate the community about...
  - TESS mission, data processing, data products, and performance
  - MAST services and tools relevant to TESS
  - Available software to analyze TESS data [including community software]
  - Ancillary data, working groups, and the follow-up program
  - How the TESS data will create new discoveries across a broad range of astronomical topics.

- Provide hands-on experience with TESS data and tools

- Discuss algorithms to facilitate TESS data analysis

- Foster TESS collaborations and science

- Provide online record of the meeting

Workshop format

- 60 participants

- 3.5 days

- ~30 talks, some 25+5 minutes and some 15+5 minutes

- Afternoon Tutorials or Panel Discussions

- Science Sprint day on Wednesday

Topics for Plenary Talks

- TESS Mission Overview

- TESS Mission Anomalies and Performance

- Algorithms/Methods to analyze TESS data depending on the science case
  - Dense stellar regions, i.e. Stellar Clusters
  - Transient Photometry, i.e. Supernova
  - Asteroseismology
  - Stellar Variability
  - Exoplanets
  - Machine Learning

- Science goals that are enabled by combining TESS with other data sets (PanStarrs, Cheops, Kepler, HST, Ground-based Follow-up)

- How to distinguish between an astrophysical event and a data anomaly

- Software available to work with TESS data (see next slide)

Breakout Tutorials

Community open source software has been developed to work with TESS data. We will solicit these groups to give brief talks on their software and provide a notebook to highlights the tool. This will be followed by time to try-out the tools.

- DSMO has agreed to support **science platforms** with the required software already installed and notebooks hosted prior to the meeting.

- Groups we plan to solicit include:
    - **MAST** is developing an FFI cutout tool. (Clara Brasseur)
    - **Kepler/K2 Guest Observer Office lightKurve** downloads Kepler/K2/TESS data directly from the MAST, works with FFIs, and creates flux time series objects. (Geert Barentsen)
    - **Other Photometry Extraction** teams using techniques like difference imaging and PSF photometry. (Ben Montet or Ryan Oelkers)
    - **Light curve systematics** correction tools (Suzanne Aigrain)
    - Teams with open source **planet candidate vetting tools** (Veselin Kostov or Eric Petigura)
    - **exoCTK** has tools to fit exoplanet light curves and calculate limb darkening (Jonathan Fraine)

Panel Discussions

- Possibilities and Challenges of All-Sky Time Series Data
  - "Big Data" Techniques that could aid in the analysis of the all sky time series data.
  - Science that could be accomplished if the data were connected to the right resources.

- Optimizing science with open data
  - How to report new objects of interest to the community.
  - Organizing follow-up observations.
  - What makes a useful community-provided high level science product.

Science Sprint Day

- Wednesday all day in Cafecon and Café.

- Participants will start scientific data analysis in the same room as the data experts.

- Allows users to make use of the tools discussed during the workshop.

- SOC will pick a few well known targets for everyone to analyze if they choose.

- Accomplishments will be reported at a plenary on Thursday morning.

- The Science Sprint Day can be dropped if the Institute cannot support it.

Potential speakers

- TESS team (e.g., Ricker, Shporer, Huang, Crossfield)
- TESS software scientists (e.g., Cody, Muirhead, Davenport)
- Archives (e.g., Fleming, Christiansen)
- Data scientists (e.g., Hogg, Foreman-Mackey, Peek)
- Asteroseismologist (e.g., Metcalf, Huber)
- Transient expert (e.g., Rest)

- Speakers will be diverse in gender and career level

Organizing committee

- ## Chairs
  - Susan Mullally, Jeff Valenti

- ## Local Organizers
  - Scott Fleming, Hannah Wakeford, Kevin Stevenson, Jonathan Fraine, Giovanni Bruno, Josh Peek

- ## Current External Organizers
  - Avi Shporer and Chelsea Huang from TESS Team
  - Elisa Qunitana from NASA Goddard Guest Investigator Program

- ## Other Potential External Organizers
  - Flatiron Institute (e.g., Foreman-Mackey)
  - TASC (e.g., Huber)

TESS Science Council endorsement

Message we sent to TESS Team:

"Attached is a revamped proposal to host a TESS Data Workshop at STScI in Mar or Apr 2019*. In deference to the TESS Science Conference at the end of July 2019, the workshop we are proposing would focus on educating the community about TESS data and tools, not TESS science. With this focus and timing, does the TESS Team endorse and support the workshop?"

Response from George Ricker (TESS PI):

"The available members of the TESS Science Council and I have quickly reviewed your proposed concept for a TESS data tools workshop at STScI in March or April 2019*. Provided that the workshop does not detract from the impact of the planned July 2019 TESS and TASC Science Conferences by increasing in scope – and thus inadvertently "scooping" the early science discoveries of TESS – the TESS Team endorses the proposed workshop and will be pleased to participate."

*Mar and Apr turn out not to be viable from an STScI scheduling perspective, but Feb is fine.

Mission office endorsements

- DMSO endorses this proposal
  - Arfon wrote, "Yes, this sounds great. You have the full support of DSMO."
  - Josh wrote, "This is a great idea, and I am all for it with all hats on."
  - DSMO is very enthusiastic about supporting science platforms for software notebooks.
- CMO endorses this proposal
  - Jason Tumlinson (responsible for CMO oversight of TESS) said this was a "great" idea, which CMO endorses.

Relevance to the STScI Science Strategic Plan

- The proposed TESS Data Workshop would address three out of four topics emphasized in the 2017 STScI Science Strategic Plan [Ferguson et al.]:

  - Planets and Exoplanets – TESS will discover ideal targets for JWST and future exoplanet characterization missions. MAST is the official archive for TESS data, though NExScI will also serve the data. This workshop will help the community appreciate our curation role.

  - Data Science – TESS data will be fertile ground for exploring machine learning algorithms. Gaussian processes were used (e.g., by colleagues at the Flatiron Institute) to analyze Kepler and K2 data. Similar algorithms will be used for TESS data. TESS data will be integrated into various DSMO and MAST initiatives, e.g., ExoMAST, the JupyterHub Science Platform, and perhaps putting data on the cloud.

  - Time-Domain Astronomy – TESS provides high-cadence time-domain measurements. Strengthening our internal focus on TESS may drive innovations that enable STScI missions to respond more rapidly to transient events.