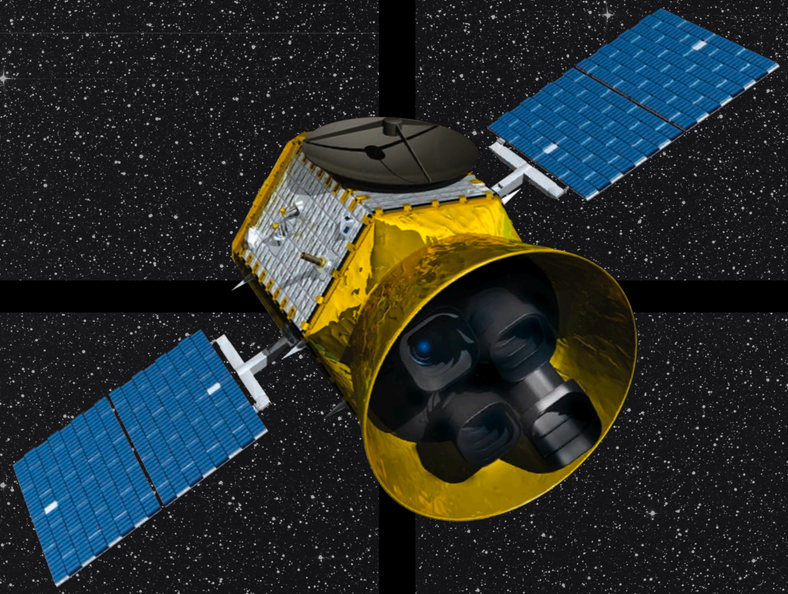
TRANSIENT SCIENCE WITH THE TRANSITING EXOPLANET SURVEY SATELLITE

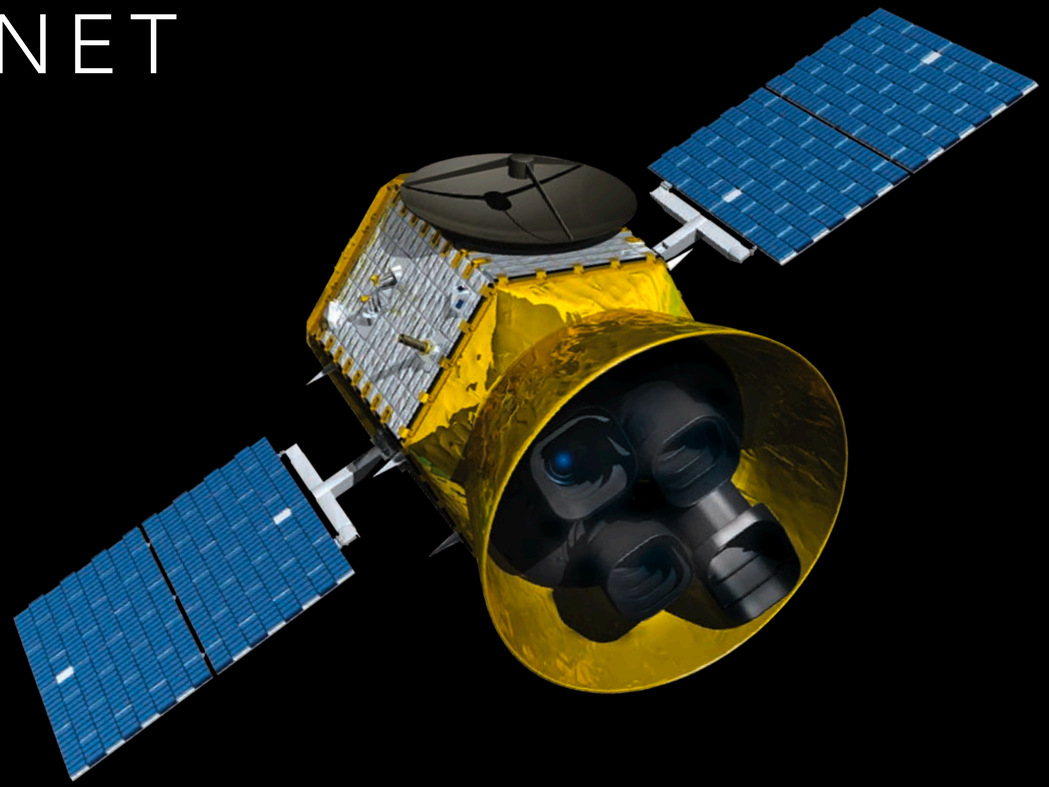


RAHUL JAYARAMAN

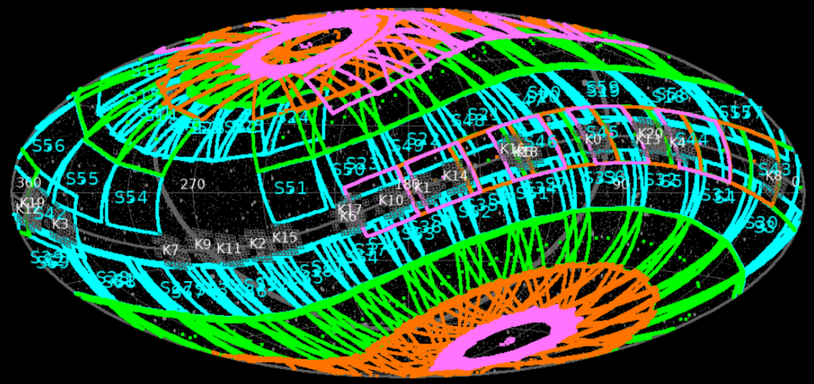
THE TRANSIENT UNIVERSE WORKSHOP

JUNE 2023

THE TRANSITING EXOPLANET SURVEY SATELLITE (TESS)



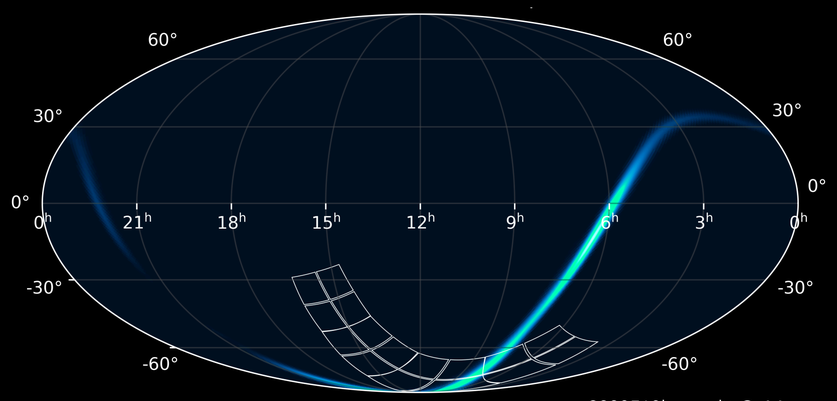
- TESS is conducting an **all-sky survey** to detect thousands of transiting exoplanets
- Wide field of view (2304 deg^2) and month(s)-long monitoring of a given patch of sky
  - Imaging cadence: currently 200s (!)
- Has found over 1000 exoplanet candidates, but it can be used for so much more…



TWO APPROACHES TO TRANSIENT DETECTION

KNOWN TRANSIENTS

- Use TESS to follow up on known EM transients observed at other wavelengths (e.g., GRBs)
- **Multi-messenger astronomy**
  - LIGO-Virgo-KAGRA (LVK) alerts



S230518h, credit G. Mo

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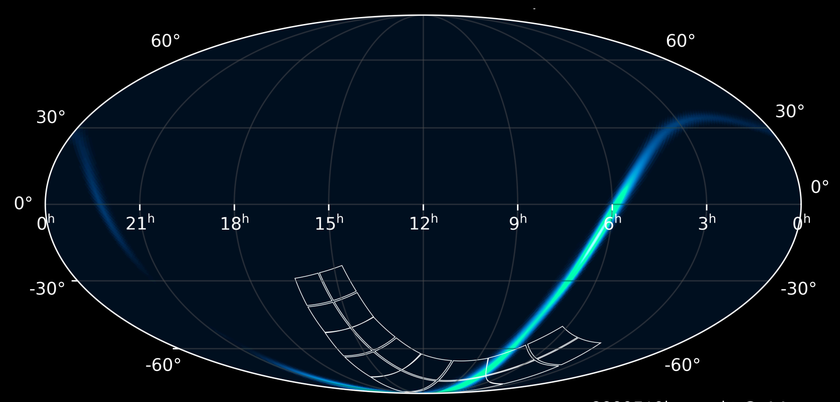
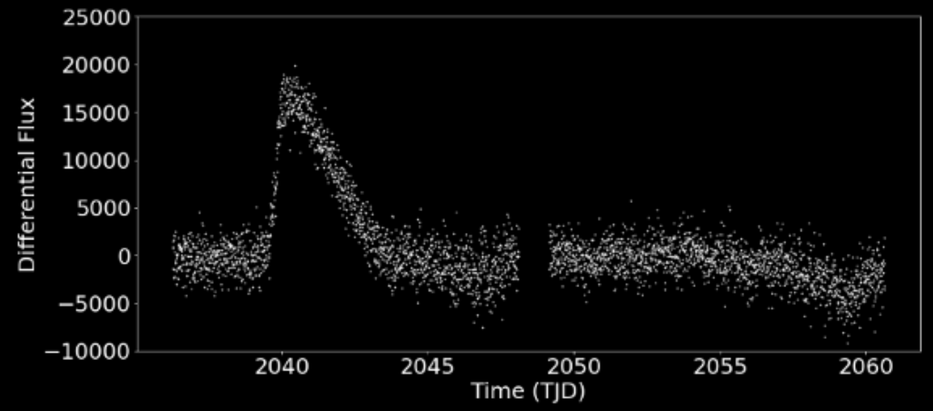


S230518h, credit G. Mo

"NEW" TRANSIENTS

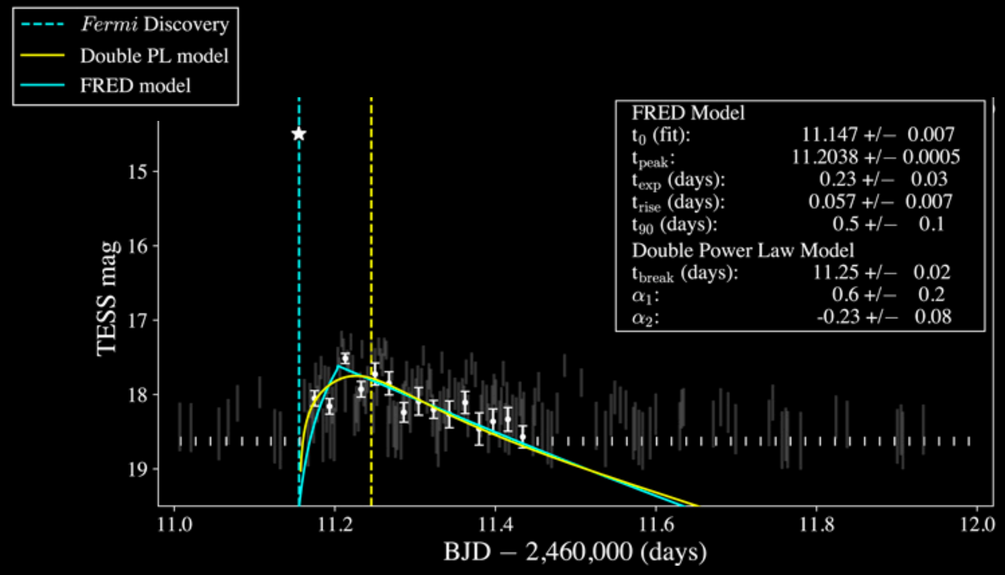
- Search for transients in TESS data that were not triggered/detected by other observatories or ground-based surveys
  - CV outbursts
  - Orphan afterglows?



ASASSN-17nq outburst

STUDYING GAMMA-RAY BURSTS WITH TESS

- Enables the study of **prompt emission** (no slewing needed!) and afterglow behavior
  - Constrain jet physics (e.g., jet breaks)
  - Finely-sampled light curves



GRB230307A, Fausnaugh+2023 (incl. RJ)

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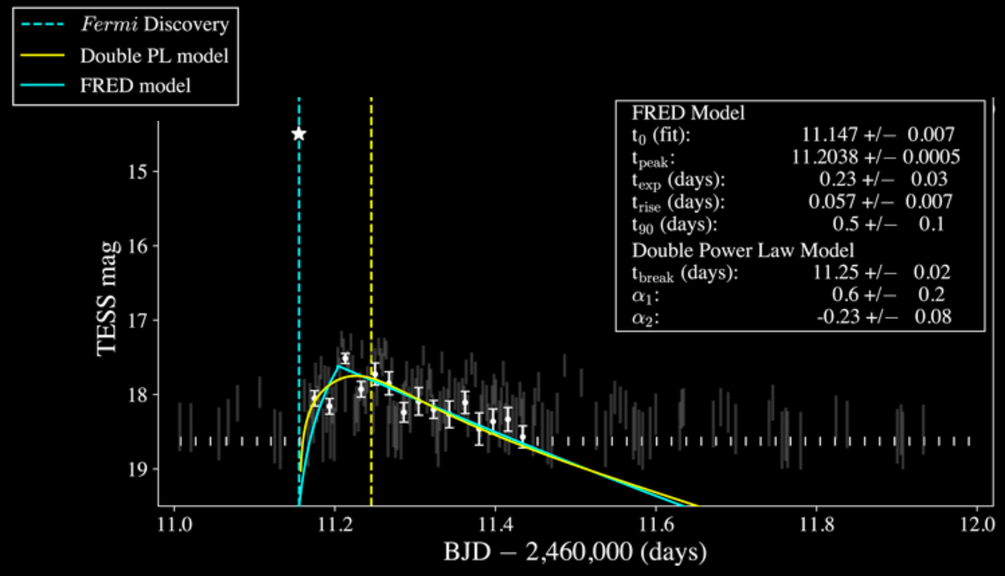
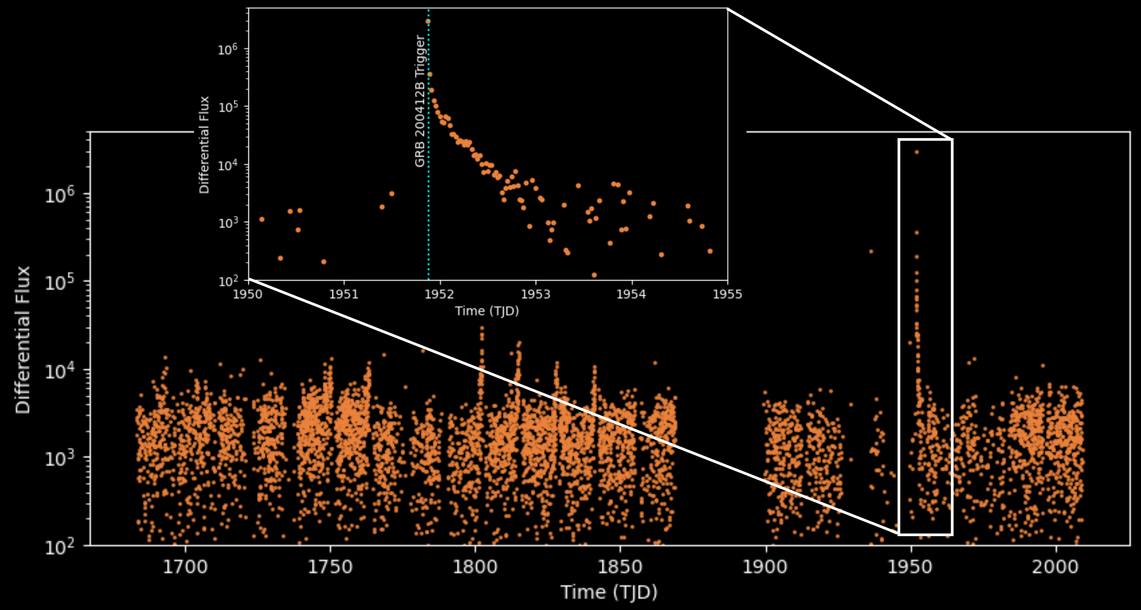


GRB230307A, Fausnaugh+2023 (incl. RJ)

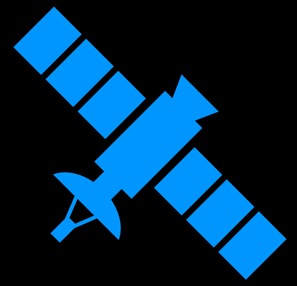
- Pre- and post-burst observations
  - Constrain pre-GRB emission (*if* it exists)
  - Monitor subsequent temporal evolution to identify **supernova** or **kilonova** components



GRB200412B, Jayaraman+*in prep*

IDENTIFYING COUNTERPARTS TO GW TRIGGERS

- Large localization areas of O(>100 deg^2) can “waste” ground-based resources when following up GW detections by the LVK network to find EM counterparts



Advantages of TESS

No slewing/tiling needed

Can find up to 3 kilonova without LVK triggers

Already observing up to 5% of the sky at any given time!

IDENTIFYING COUNTERPARTS TO GW TRIGGERS

- Large localization areas of O(>100 deg^2) can "waste" ground-based resources when following up GW detections by the LVK network to find EM counterparts

- Useful for all three types of compact object mergers:
  - Those with BH: Establish limits on any possible emission (e.g., that observed in Graham+2020)
  - Those with NS: Identify kilonovae and early-time behavior to constrain merger physics
- For BNS mergers, can also identify any prompt emission from the associated sGRBs

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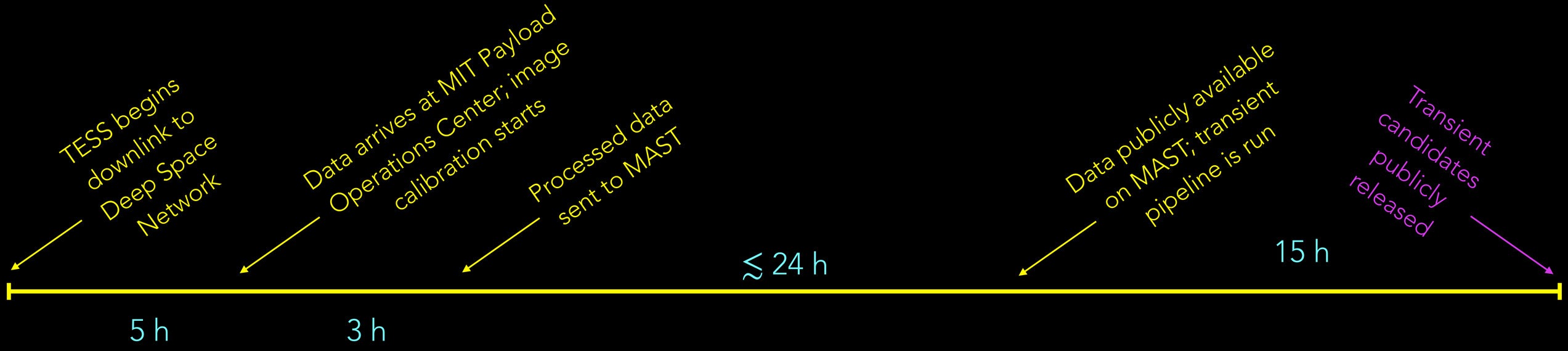
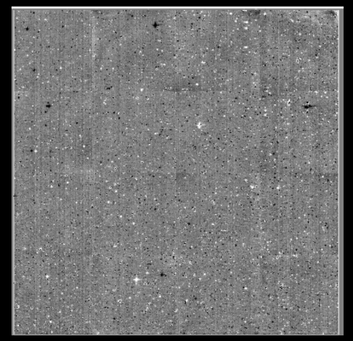
TESS AS A TRANSIENT DISCOVERY ENGINE

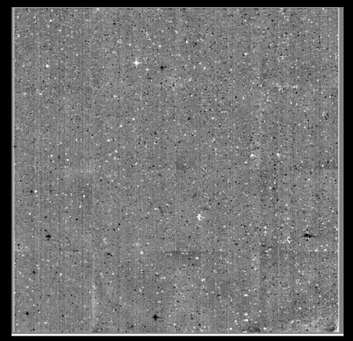
- Early-release images and weekly downlinks in TESS's Extended Mission 2 allow for rapid identification and follow-up of TESS Transients
  - The TICA pipeline processes images within 36 h of downlink (Fausnaugh+2020)
  - Transient detection pipeline runs immediately afterward, and candidates are released on a publicly available website

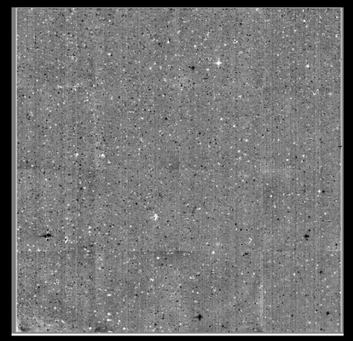


THE TESS TRANSIENT DETECTION PIPELINE

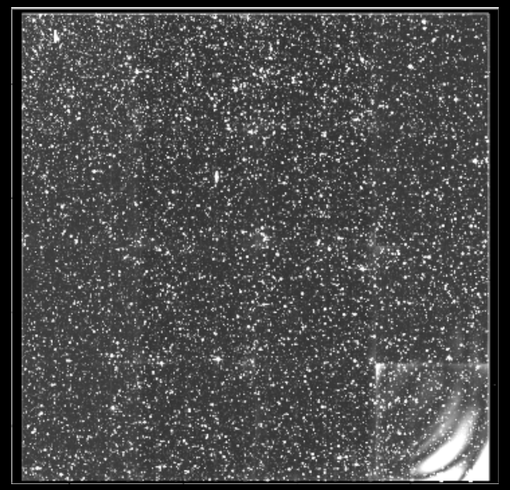
- Runs after every data downlink
- Steps (~12 h total per downlink):
  - Difference Imaging + RMS Image generation
  - Source Extractor
  - Classification (convolutional neural network)
  - Photometry (PSF fitting)
  - Clustering (HDBSCAN) on the generated light curves
  - Public dissemination





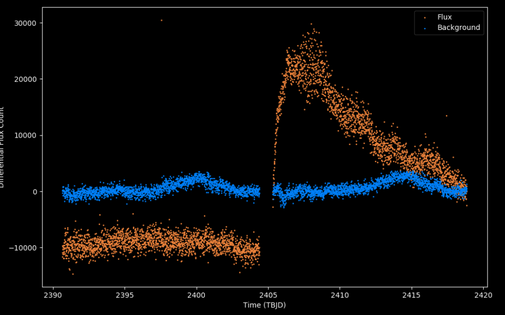


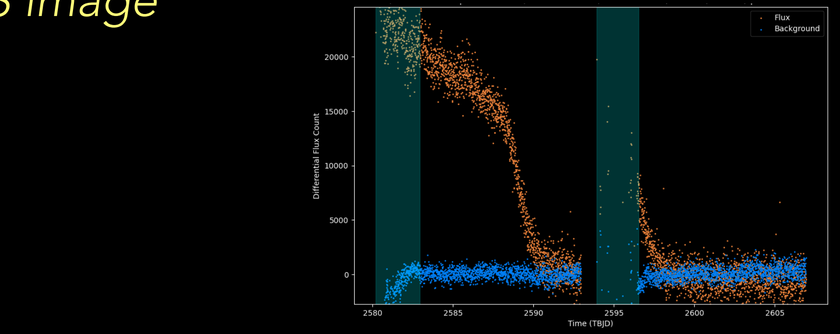
Difference Imaging



RMS image

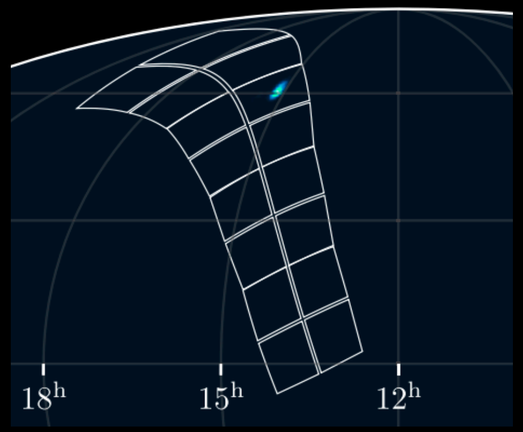
Photometry (based on difference images)



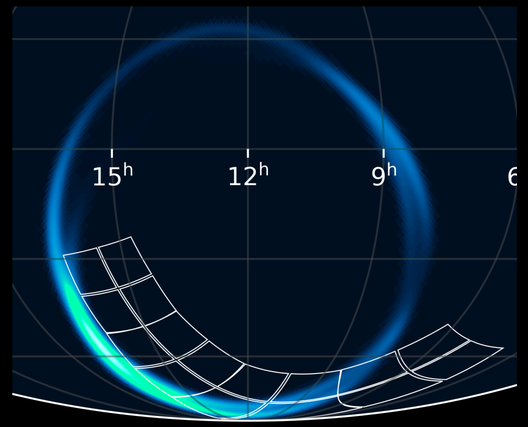


THE TESS TRANSIENT DETECTION PIPELINE

- Useful to search a large sky localization area, if the FoV is overlapping



Mo+2023 (incl. RJ)



S230520ae, credit G. Mo

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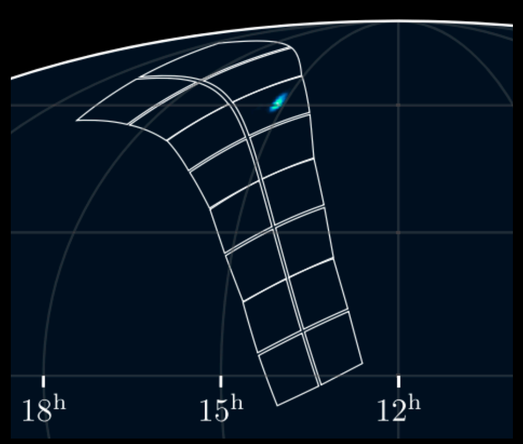

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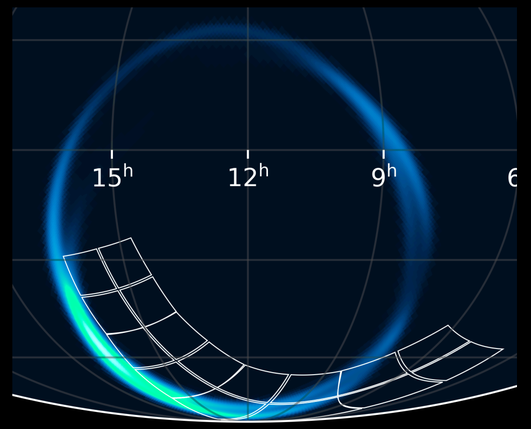
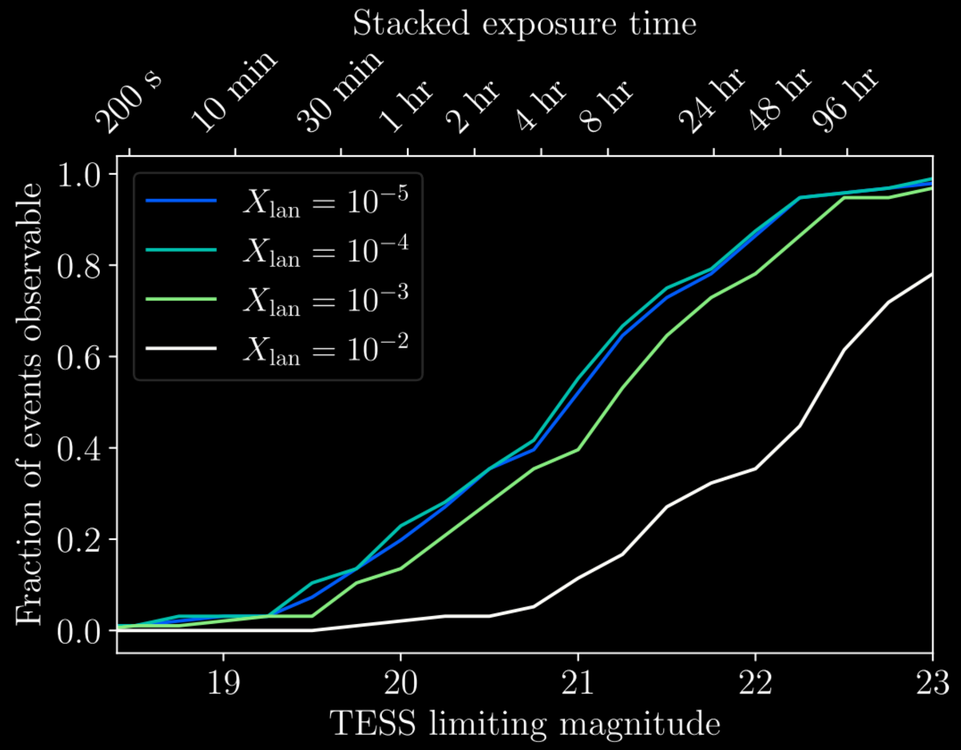


S230520ae, credit G. Mo



Mo+2023 (incl. RJ)

- Difference imaging can identify transients that peak as faint as T_{mag} ~ 20, or 22 with binning
  - Pipeline characterization in progress
- *Very* useful for short-timescale transients that may be missed from the ground

CONCLUSIONS

- TESS is poised to play an invaluable role in transient science
  - Large FOV & 200-second cadence light curves can be used to constrain transient physics, especially at early times (e.g., GRB prompt emission)
  - Can provide complementary information to other high-energy observatories, as well as enable multi-messenger astronomy
  - Can act as a discovery engine on its own for unique classes of transients
- **It's an exciting era for transient science with new observatories coming online throughout the rest of this decade!**