A Survey of Comets Using TESS

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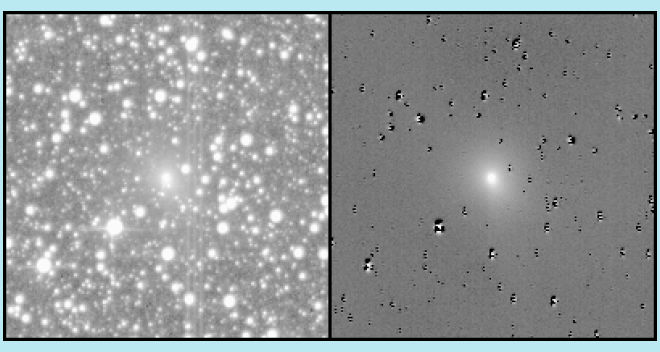
Introduction

We are using the TESS full frame images to perform a survey of up to 100 comets that serendipitously pass through the spacecraft's field of view. By monitoring the comets' short- and long-term temporal behavior, we can track secular changes in activity, measure the nucleus spin state, map and analyze variability in the coma morphology, and search for spontaneous outbursts. The data are especially useful for identifying rotation periods longer than 24 hours, which are under-sampled in ground-based observations, and for capturing the onset and early stages of outbursts. By aligning and co-adding numerous images, we can also search for dust trails that will constrain the comets' dust properties and total mass loss rates. For specific high-profile comets, including potential spacecraft targets, we perform more detailed analyses to better characterize the activity for planning any future missions. Some preliminary results are illustrated here.

Data Reduction

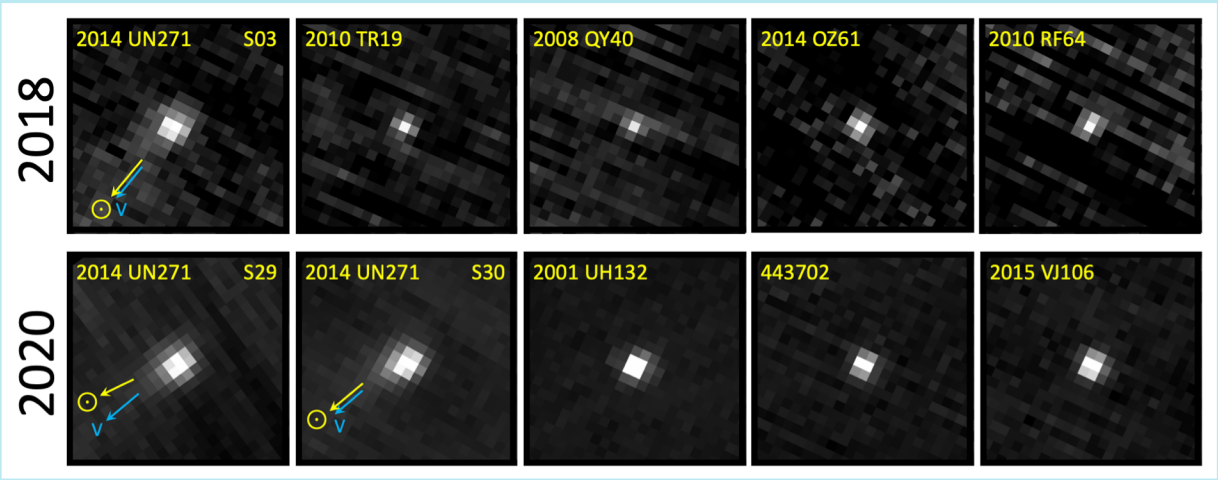
We have made use of the Difference Image Analysis routines (Oelkers & Stassun, *AJ*, **156**, 132, 2018) to remove the scattered light and background stars. We use these frames to perform our aperture photometry and image analysis.

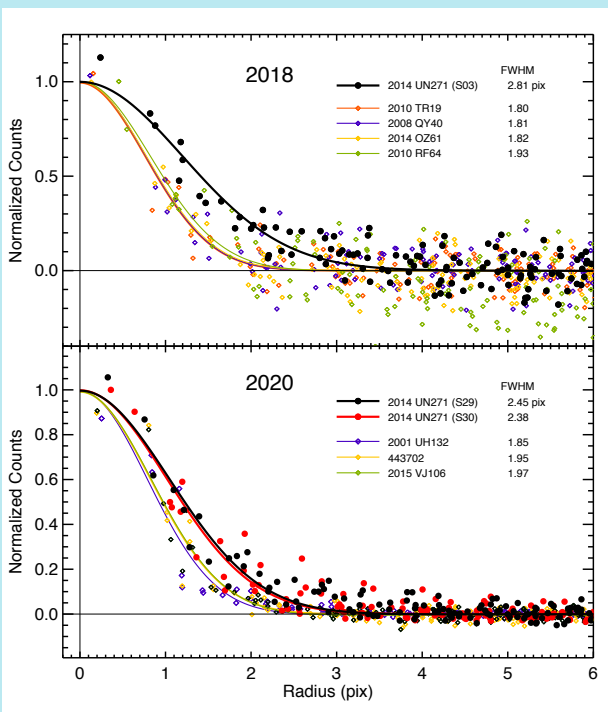


Example of the star and background removal, showing the region of a sample frame (tess2018284152940-s0003-2-3-0123-s_ffic_sa) surrounding comet 46P/Wirtanen before (left) and after (right) the DIA cleaning process. The images are displayed with the same logarithmic scale.

Comet C/2014 UN271 Bernardinelli-Bernstein

Comet B-B was discovered using data from 2014-2018, when the comet was as far as 30 AU from the Sun, and may have the largest nucleus of any known comet. We used TESS observations from Sep/Oct 2018 (Heliocentric distance 23.2 AU, Sector 3) and from Aug-Oct 2020 (21.1 AU, Sectors 29-30) to show that it was already active before reaching 23 AU.



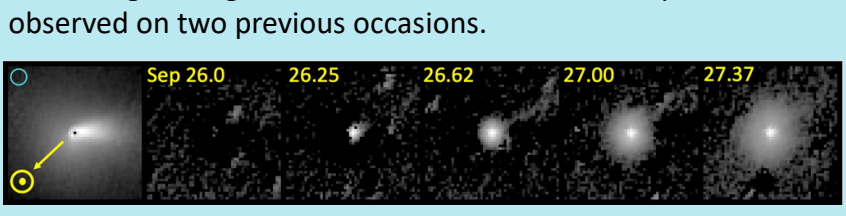


Above: Coadded images of 2014 UN271 from 2018 (S03, 976 frames) and 2020 (S29, 3585 frames; S30, 3410 frames) compared to KBOs of similar brightness and proper motion, processed with the same reduction procedures. The comet shows clear evidence for a coma with a sunward asymmetry when compared to the bare KBO images.

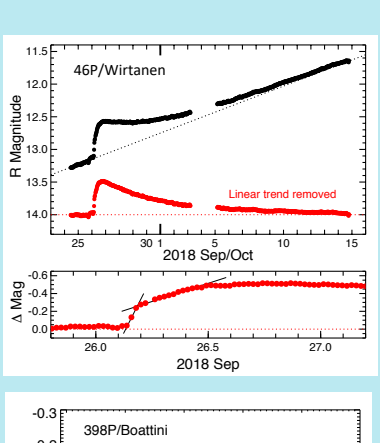
Left: Radial profiles of 2014 UN271 and the KBOs shown in the images above, fit with Gaussian curves with the listed FWHM. The comet has a broader profile in each case, highlighting the extended emission.

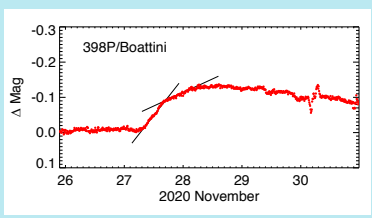
Cometary Outbursts

Spontaneous cometary outbursts are not well understood, but represent massive releases of energy that factor into the comet's total energy budget and mass production. We have discovered at least two outbursts in our early data analyses. Comets 46P/Wirtanen and 398P/Boattini experienced spontaneous outbursts during the TESS observations, recording the initial brightening of the outburst in detail. This phase of cometary outbursts has only been observed on two previous occasions.



Above: Images showing the expansion of CN gas in the 0.5 mag outburst in comet 46P/Wirtanen. The pre-outburst dust coma and tail (left panel) have been removed to reveal the changes occurring during the outburst (Farnham et al., *ApJ Lett*, **886**, L24, 2019.)

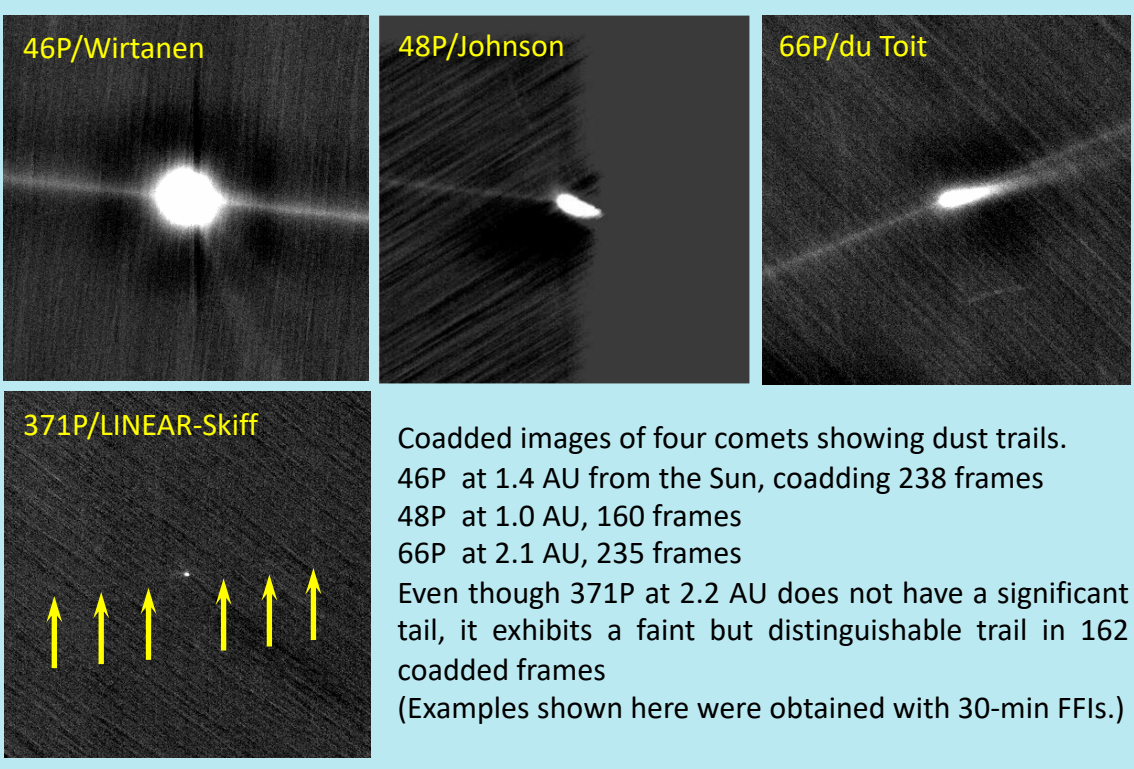




Right: Photometry showing the lightcurves of 46P/Wirtanen and 398P/Boattini, both exhibiting a two-phase brightening, in which the first phase is steep, followed by a shallower brightening to the peak.

Cometary Dust Trails

Dust trails are composed of large dust grains that spread out along the comet's orbit and represent a large fraction of the mass production of comets that exhibit them. They are more commonly discovered using infrared observations, because large grains are more efficient at emitting heat than they are at scattering sunlight at visible wavelengths, however, by coadding the large number of images means that trails can be detected in the TESS observations. We have already discovered at least four trails that were not previously known. Work is progressing on these trails to determine how much mass they represent in each comet.



Coadded images of four comets showing dust trails.
46P at 1.4 AU from the Sun, coadding 238 frames
48P at 1.0 AU, 160 frames
66P at 2.1 AU, 235 frames
Even though 371P at 2.2 AU does not have a significant tail, it exhibits a faint but distinguishable trail in 162 coadded frames
(Examples shown here were obtained with 30-min FFIs.)