Interactive Figures in the AAS Journals

Peter K. G. Williams
American Astronomical Society and Center for Astrophysics | Harvard & Smithsonian

peter.williams@aas.org
https://newton.cx/~peter/
Questions? Tweet @pkgw

Electronic publishing makes it possible to convey scientific content not just with static images but with *interactive, exploratory visualizations*. This is a big opportunity to improve the way we do science! So, the American Astronomical Society (AAS, publisher of the *Astrophysical Journal*, the *Planetary Science Journal*, and others) is working to make it as easy as possible to include "interactive figures" in your articles. **This year AAS is launching new Jupyter-based tools to help you create interactive figures for two common data types: time series and sky images.**

Interactively Explore Your Timeseries Data …

Everything starts with the data! Here we download a Kepler light curve and import it as a new Astropy TimeSeries object — essentially a table with some extra features.

The first few columns and rows of the table look like this.

The package aas_timeseries can turn these data into interactive graphics. Doing so is easy! The API is similar to existing libraries like Matplotlib.

This is the best part! Unfortunately, since this poster is static, we can't show you how you can zoom in and out of your data, phase them on the fly, add and remove additional datasets on the fly, or configure the display of the time axes. But you can do all this and more! Ask the presenter to show you if they're around, or follow the link given in the QR code over there ↘

You can add all sorts of annotations to your plots, including error bars, textual notes, horizontal and vertical ranges, and so on.

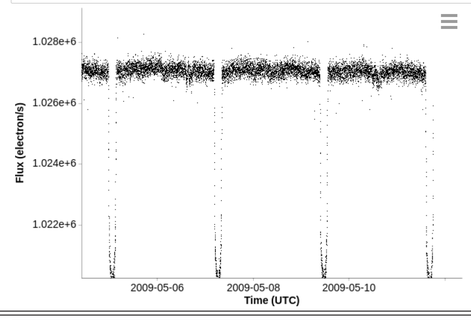
Not shown here, you can also create predefined views that emphasize different parts of your data. No more reproducing your data in multiple figures to convey different important features!

Once again, if this wasn't a static, preprinted poster, you could navigate this dataset and its presentation interactively.

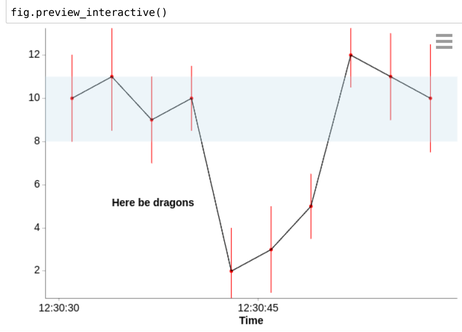
```
In [1]: from astropy.utils.data import get_pkg_data_filename

        basename = 'timeseries/kplr010666592-2009131110544_slc.fits'
        filename = get_pkg_data_filename(basename)

        from astropy.timeseries import TimeSeries

        ts = TimeSeries.read(filename, format='kepler.fits')

In [2]: ts[:5]

Out[2]: TimeSeries length=5
```

time	timecorr	cadenceno	sap_flux	sap_flux_err	sap_bkg	sap_bkg_err	pdcsap_flux	pdcsap_flux_err	s
	d		electron / s	electron / s	electron / s	electron / s	electron / s	electron / s	
object	float32	int32	float32	float32	float32	float32	float32	float32	
2009-05-02T00:41:40.338	6.630610e-04	5500	1.0270451e+06	1.4041933e+02	3.7480554e+03	2.2283568e+00	1.0346376e+06	2.4780812e+02	
2009-05-02T00:42:39.188	6.630857e-04	5501	1.0271844e+06	1.4042902e+02	3.7491572e+03	2.2283657e+00	1.0347789e+06	2.4594159e+02	
2009-05-02T00:43:38.045	6.631103e-04	5502	1.0270762e+06	1.4038968e+02	3.7502588e+03	2.2283745e+00	1.0346701e+06	2.4408449e+02	
2009-05-02T00:44:36.894	6.631350e-04	5503	1.0271414e+06	1.4042482e+02	3.7513606e+03	2.2283831e+00	1.0347365e+06	2.4229922e+02	
2009-05-02T00:45:35.752	6.631597e-04	5504	1.0271569e+06	1.4039404e+02	3.7524626e+03	2.2283916e+00	1.0347527e+06	2.4051416e+02	

```
In [3]: from aas_timeseries import InteractiveTimeSeriesFigure
        fig = InteractiveTimeSeriesFigure()

        markers = fig.add_markers(time_series=ts, column='sap_flux', label='SAP Flux')
        fig.xlabel = 'Time (UTC)'
        fig.ylabel = 'Flux (electron/s)'

In [4]: fig.preview_interactive()
```




```
In [5]: from astropy import units as u
        small_ts = TimeSeries(time_start='2016-03-22T12:30:31', time_delta=3 * u.s, n_samples=10)
        small_ts['flux'] = [10, 11, 9, 10, 2, 3, 5, 12, 11, 10]
        small_ts['error'] = [2, 2.5, 2, 1.5, 2, 2, 1.5, 1.5, 2., 2.5]

In [6]: from aas_timeseries import InteractiveTimeSeriesFigure
        fig = InteractiveTimeSeriesFigure()

        markers = fig.add_markers(time_series=small_ts, error='error', column='flux', label='Flux')
        markers.color = 'red'

        line = fig.add_line(time_series=small_ts, column='flux', label='Flux')
        hrange = fig.add_horizontal_range(8, 11, label='Horizontal Range')
        text = fig.add_text(time=small_ts.time[1], value=5, text='Here be dragons', label='Text')

        fig.preview_interactive()
```



… And Your Sky Images

The same way that the aas_timeseries package lets you interactively explore time-based data, the AAS WorldWide Telescope (WWT) and pywwt, its Python frontend, let you interactively explore images of the sky.

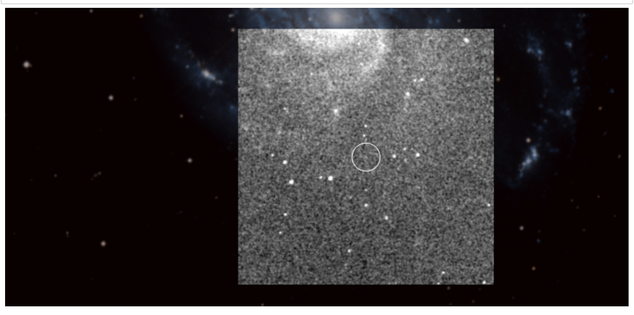
Here, we use the SkyView web service to download a 2MASS image centered on the location of SN 2011fe.

Here too, this printed poster isn't able to show you the best part of this tool: interactive image exploration right inside your Jupyter notebook!

Widgets linked to the WWT view allow on-the-fly control of how your data are visualized.

You can also control the background imagery that provides the context for your data, and add the usual complement of annotations.

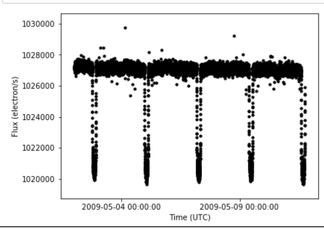
```
In [1]: from pywwt.jupyter import WWTJupyterWidget
        from astropy import units as u
        from astropy.coordinates import SkyCoord
        from astroquery.skyview import SkyView

        WARNING: AstropyDeprecationWarning: astropy.extern.six will be removed in 4.0, use the six module d
        irectly if it is still needed [astropy.extern.six]

In [2]: img_list = SkyView.get_images(position='SN 2011FE', survey='2MASS-K', pixels=500)
        my_hdu = img_list[0][0]

In [3]: wwt = WWTJupyterWidget()
        wwt
```



```
In [4]: img_layer = wwt.layers.add_image_layer(my_hdu)
        img_layer.controls

        /a/lib/python3.7/site-packages/reproject/interpolation/core_celestial.py:26: FutureWarning: Convers
        ion of the second argument of issubdtype from `float` to `np.floating` is deprecated. In future, it
        will be treated as `np.float64 == np.dtype(float).type`.
          if not np.issubdtype(array.dtype, np.float):

        Opacity:  Stretch: linear
        Coarse min: 344  Coarse max: 370
        Fine min/m…  355.30 – 365.40

In [5]: wwt.layer_controls

        Hydrogen Alpha Full Sky Map  Digitized Sky Survey (Color)

In [6]: sn11_coord = SkyCoord.from_name('SN2011fe')
        circle_annot = wwt.add_circle(sn11_coord, radius= 0.01 * u.deg)
```

Then, Share Your Interactives in a Journal …

```
In [5]: fig.save_static('my_figure', format='pdf')
        fig.export_interactive_bundle('my_figure.zip')
```



Once you've created the perfect data exploration experience, it's easy as pie to export your setup into the files that you'll need to include them in your AAS manuscript.

The pywwt module has recently acquired the same kind of functionality as well.

```
\documentclass{aastex63}

% ...

In \autoref{f.10666592} we show the light curve data.

\begin{figure}
  \begin{interactive}{timeseries}{my_figure.zip}
    \includegraphics[width=\linewidth]{my_figure.pdf}
  \end{interactive}
  \caption{A lovely lightcurve of KIC~10666592. This figure is available
    online as an interactive figure: the interaction allows you to pan and
    zoom on the individual data points, and select pre-defined views that
    isolate individual transits.}
  \label{f.10666592}
\end{figure}

% Down at the bottom ...

\software{Astropy \citep{astropy:2013, astropy:2018}, aas-timeseries
  (\url{https://aas-timeseries.readthedocs.io/}), ...}
```

In your AASTeX LaTeX file, a special "interactive" environment marks your interactive figure. The output PDF can only show the static form of your figure, but the online published article will include the interactive version.

AAS journals take accessibility seriously: it is important that your caption describe the interaction for those who cannot experience it.

It is also important to cite the software that you use! AAS Publishing wants to promote the recognition of software as an essential category of research output.

In Figure 1 we show the light curve data.

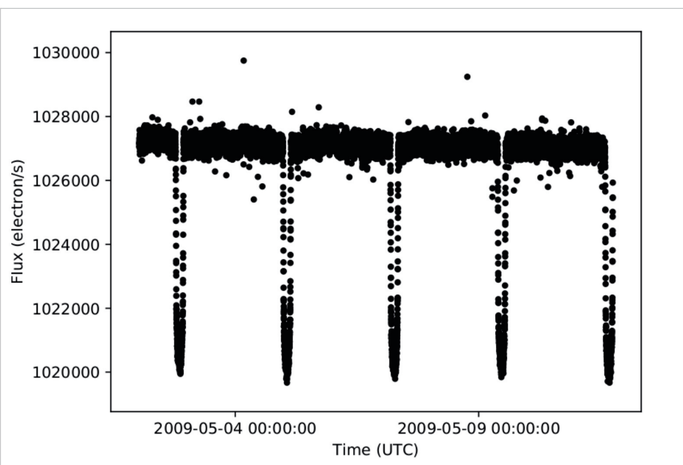


Figure 1. A lovely lightcurve of KIC 10666592. This figure is available online as an interactive figure: the interaction allows you to pan and zoom on the individual data points, and select pre-defined views that isolate individual transits.

Start interaction

Download figure:

Standard image | High-resolution image | Export PowerPoint slide | Figure data file

Here is some more text to help you envision how wonderful your interactive figure will look in the midst of your incisive, engaging scientific prose.

In your final published article, readers will initially see the static version of your figure. This is important for accessibility, archival security, and performance for people with low-power devices or slow internet connections.

Yet again, this static image can't show the best part: when readers click the blue "Start interaction" button, the static image will be replaced with the exact same interface you used to understand your data! Just like you, they will be able to do things like pan, zoom, and turn on and off different marker sets.

By clicking the "Figure data file" button, readers can download the files that define your figure — including a CSV table of the underlying data. No more squinting to manually read X and Y coordinates off of somebody else's plot!

… Or Your Personal Website

```
<!DOCTYPE html>

<html lang="en">
  <head>
    <meta http-equiv="content-type" content="text/html; charset=UTF-8">
    <meta http-equiv="X-UA-Compatible" content="IE=edge,chrome=1">
    <style type="text/css">
      .intfig { width: 650px; height: 400px; }
    </style>
  </head>
  <body>
    <h1>Welcome to My Personal Webpage</h1>
    <p>Explore the data from my latest paper!</p>
    <iframe class="intfig" src="my_figure/index.html">
      <p>Unfortunately your browser doesn't support iframes.</p>
    </iframe>
  </body>
</html>
```

Interactive figures are simple HTML documents that are designed to be embedded in other pages as iframes. So you can embed them anywhere you can author HTML content — for instance, on your personal website.

Looking for inspiration about what else you can do with interactive figures? Go to http://astroexplorer.org/ and search for the "Interactive Figures" content type to see what other authors have created!

Want to actually see all of these interactive features in action? Check out the links at this URL:

https://journals.aas.org/landing/interactive-figures-201909/

Or scan the QR code.

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