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chromatic & chromatic_fitting

New open-source tools for precise atmospheric
spectroscopy with JWST and beyond 

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The motivation behind **chromatic** and **chromatic_fitting**

1. Address Science Goals

- compare reductions
- simplify and standardize calculations
- produce publication-standard visuals
- extract reliable spectra and spectral retrievals

2. Follow Good Practice Guidelines:

- open-source
- user-friendly
- community-driven
- transparent
- versatile
- regularly maintained

The **chromatic** package is a user-friendly, open-source tool for working with spectroscopic data.

With **chromatic** we define a spectroscopic light curve object (a Rainbow ) to provide easy access to time, wavelength, flux, and uncertainty attributes.

```
r = Rainbow().for reagby
```

chromatic

github.com/zkbt/chromatic

chromatic allows reading and writing spectral datasets from/to a variety of formats, including JWST pipeline, Eureka!, .txt files, .csv files, and many more!

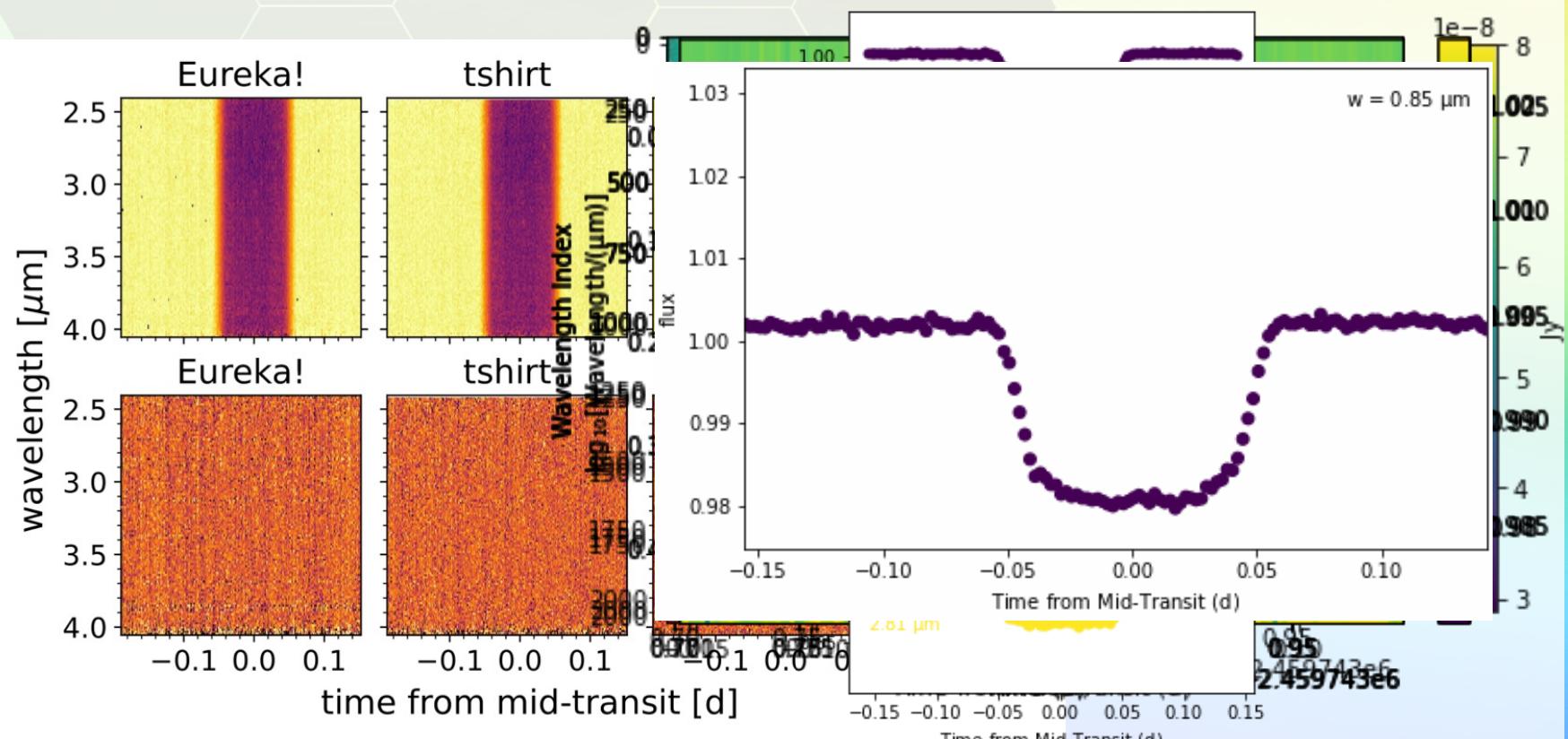
There is also a template to create readers for your own pipeline products!

```
r = fitRainbow(format='from_stsdas')
```

This tool simplifies many common calculations, produces a plethora of visualizations, and provides an easy way to compare different data reductions.

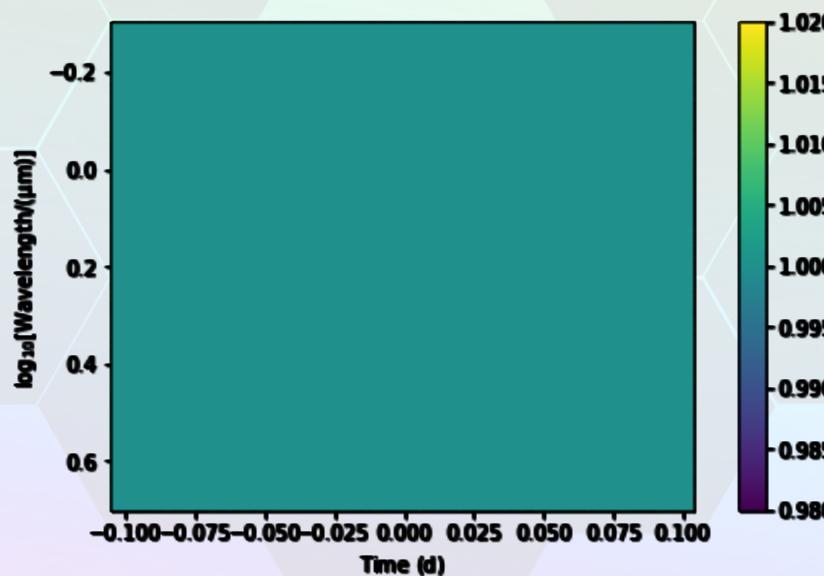
`r=(Rainbow("tshirt"))`

`.fold()
.animate()`



With **chromatic** we can also simulate planets and systematics for easy testing of modelling tools.

```
r = SimulatedRainbow().injectSystematics()
```



chromatic_fitting

github.com/catrionamurray/chromatic_fitting

chromatic_fitting is tool, built on top of **chromatic**, to efficiently model time-series spectroscopic data, and produce transmission (or emission) spectra.

chromatic_fitting also has the flexibility to:

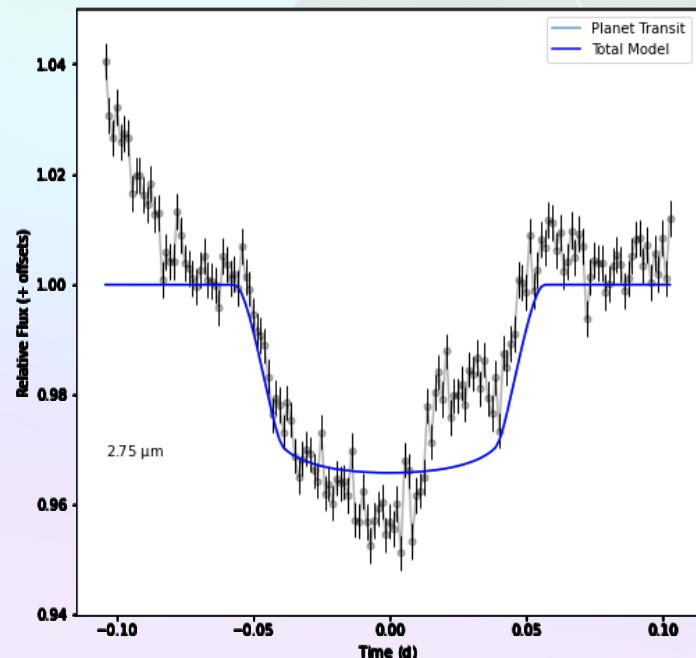
- Use/combine different models
- Create your own models
- Easily switch between a 'white light' fit or multi-wavelength fitting (either simultaneously or separately)
- Heavily customize the fitting and sampling

chromatic_fitting

github.com/catrionamurray/chromatic_fitting

`chromatic_fitting` can combine any number of: transit, eclipse, polynomial (in time, x/y position, etc.), exponential, step, Gaussian Process, or user-defined models and fit for all parameters at once.

Therefore, in just one fit we can account for the spectral signatures imprinted by planets, stellar activity and instrumental systematics.



$$\begin{aligned} m^m &= \text{TransitModel}(t) \\ m_1 * m_2 &= \text{ExponentialModel}(t) * \text{StepModel}(t) \\ m_2 + m_3 &= \text{PolynomialModel}(t) + \text{PolynomialModel}(x) \\ m_3 \oplus m_4 &= m_1 * m_2 + \text{PolynomialModel}(y) \\ &+ \text{PolynomialModel}(bkg) \end{aligned}$$

chromatic_fitting

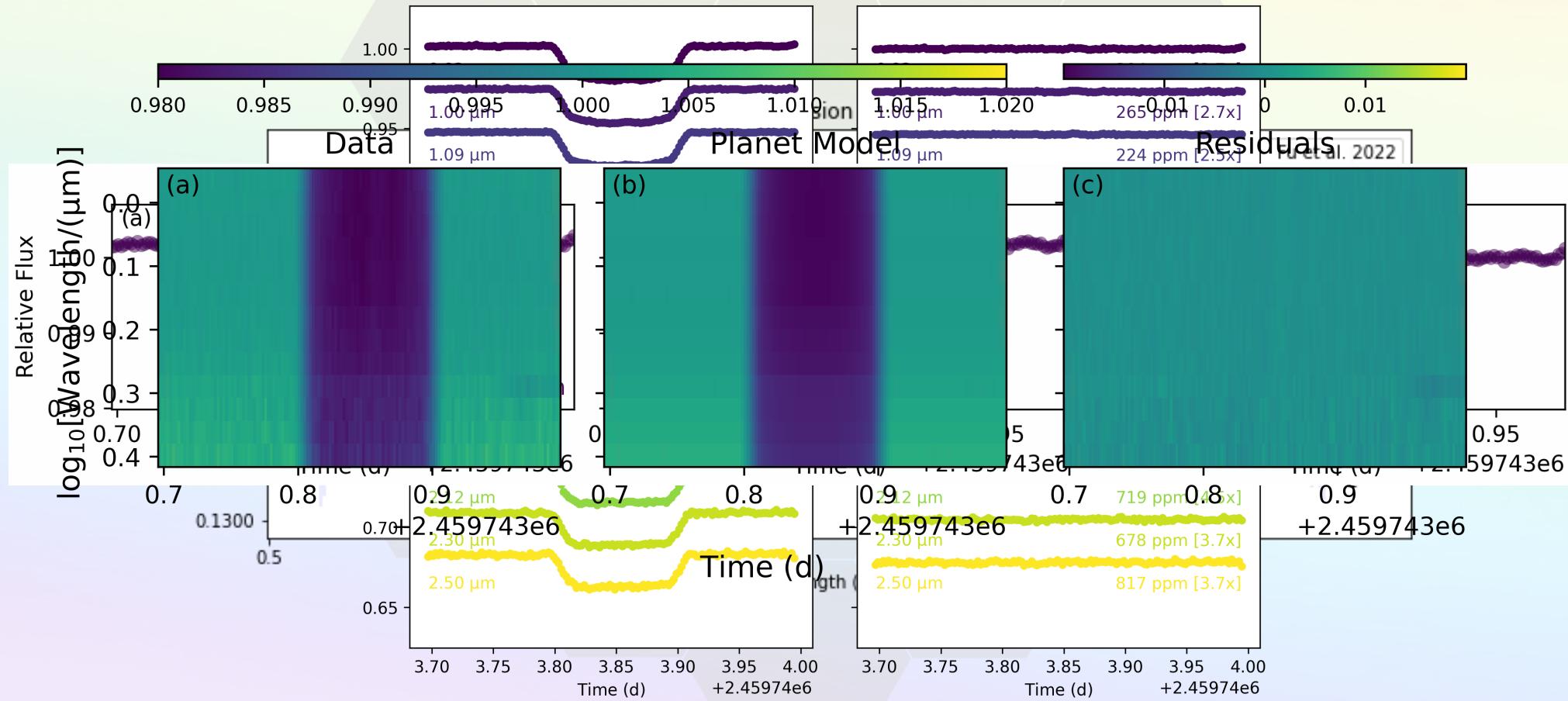
github.com/catrionamurray/chromatic_fitting

```
m = TransitModel()  
  
m.setup_parameters(  
    period= 5.508  
    epoch= Fitted(Uniform, lower=..., upper=...)  
    impact_parameter= Fitted(ImpactParameter, ...)  
    stellar_radius= Fitted(Normal, mu=..., sigma=...)  
    stellar_mass= Fitted(...)  
    radius_ratio= WavelikeFitted(Normal, mu=..., sigma=...)  
    limb_darkening= WavelikeFitted(Normal, mu=[...], sigma=...)  
    baseline= WavelikeFitted(...)  
    )  
  
m.attach_data(r)  
m.setup_likelihood(inflate_uncertainties=True, mask_outliers=True,...)  
m.sample(tune=2000, draws=2000, chains=4,...)
```

chromatic_fitting

github.com/catrionamurray/chromatic_fitting

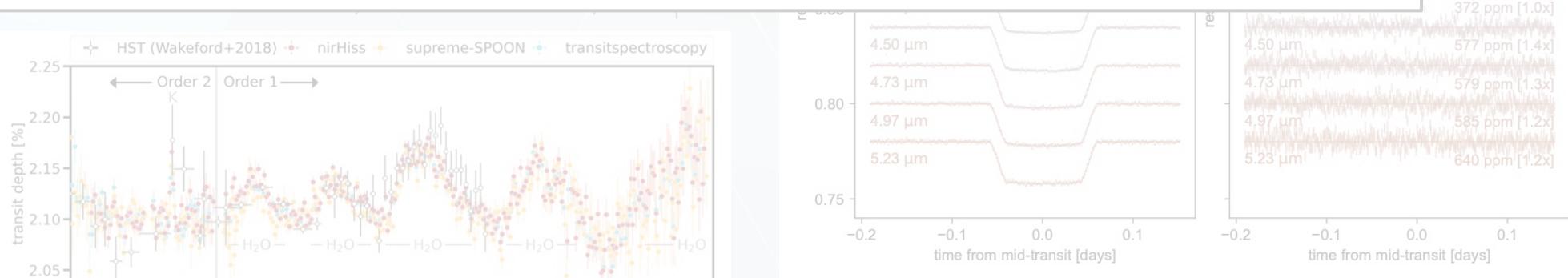
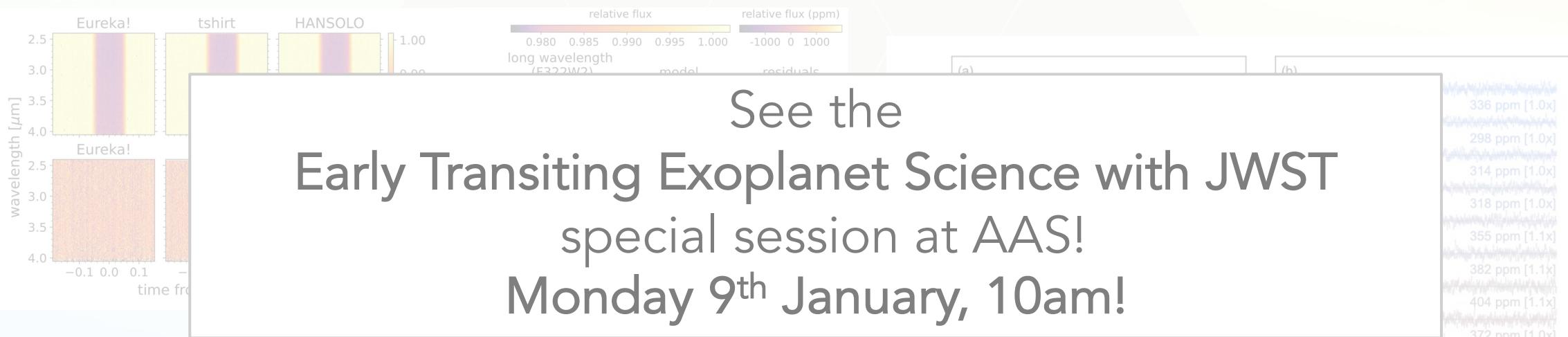
Fit to HAT-P-18b (directly from JWST Pipeline Stage 3)



HAT-P-18b (directly from JWST Pipeline Stage 3)

JWST ERS Data

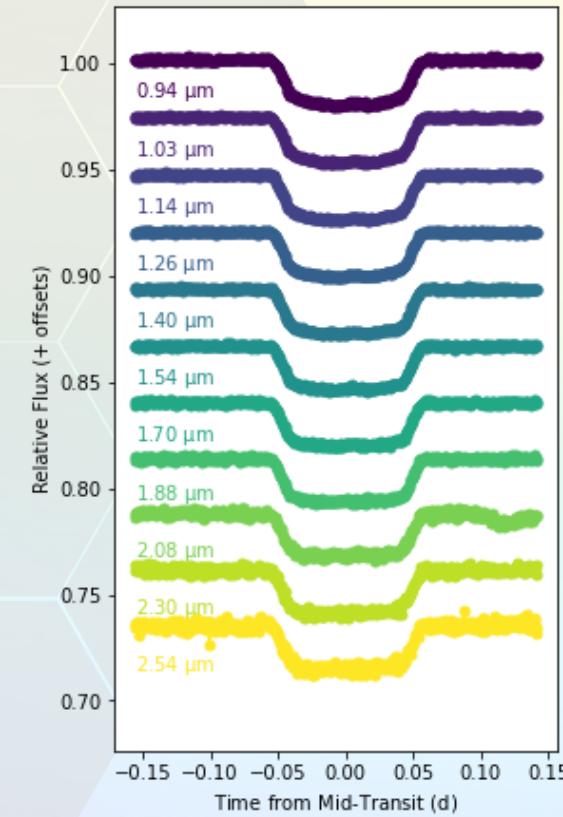
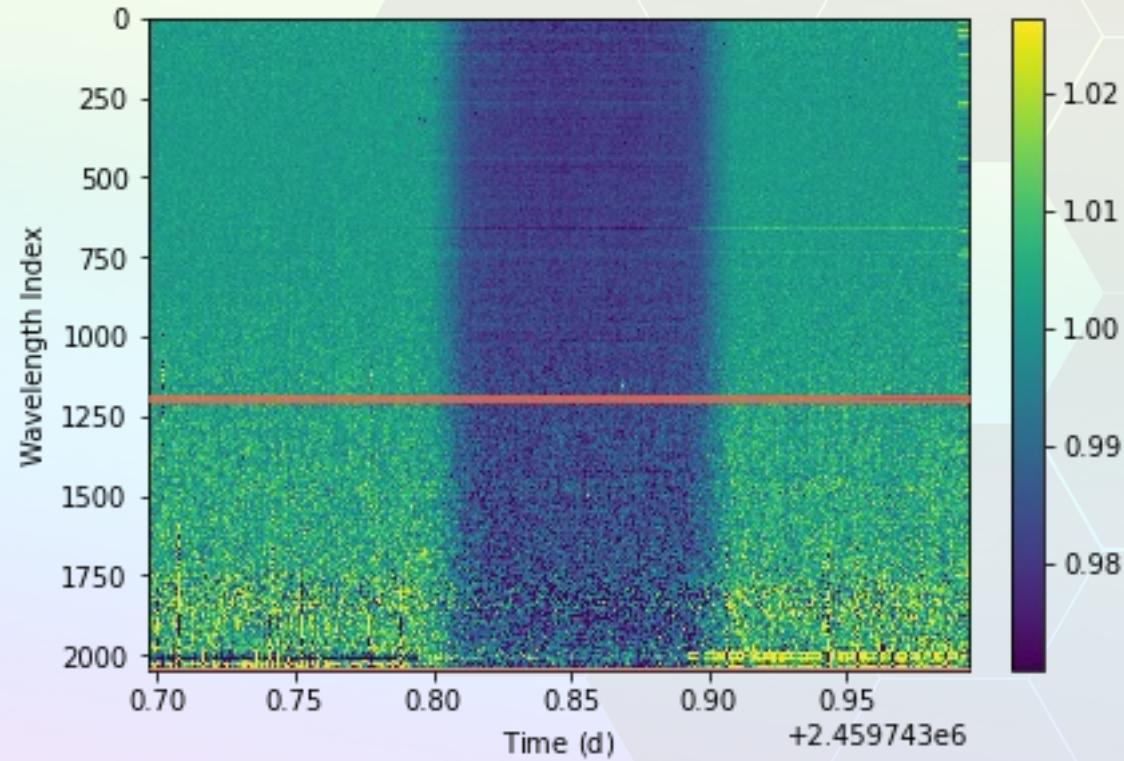
The **chromatic** and **chromatic_fitting** tools were developed alongside the JWST ERS program and successfully applied to the first results from several JWST instruments.



JWST Transiting Exoplanet Community ERS Team, 2022

In Summary...

chromatic

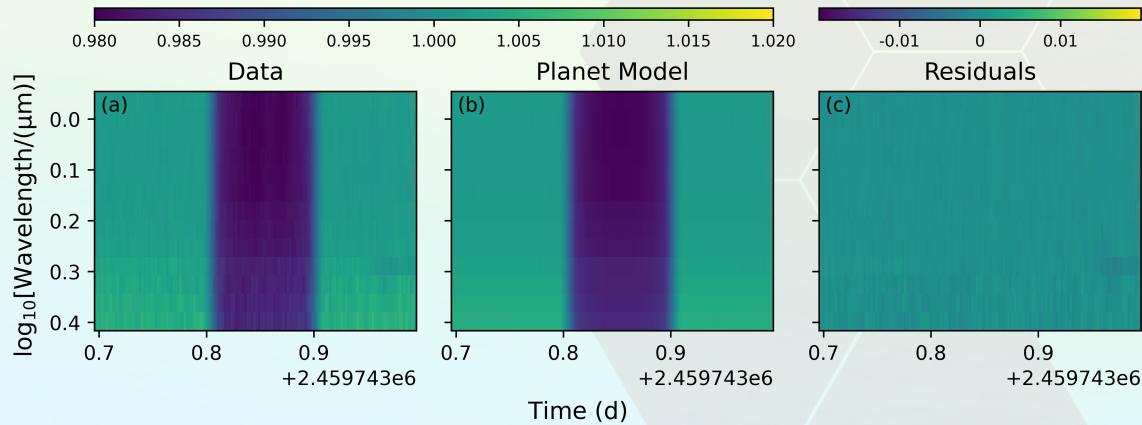


HAT-P-18b (directly from JWST Pipeline Stage 3)

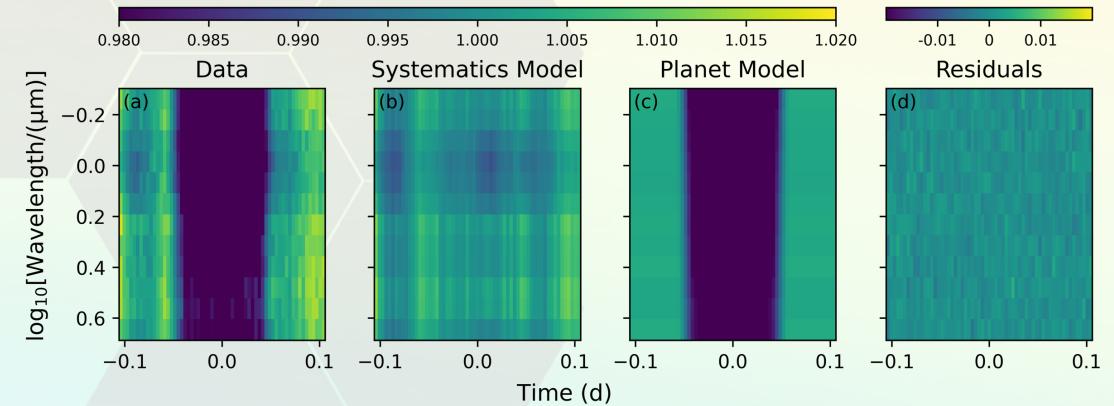
In Summary...

chromatic_fitting

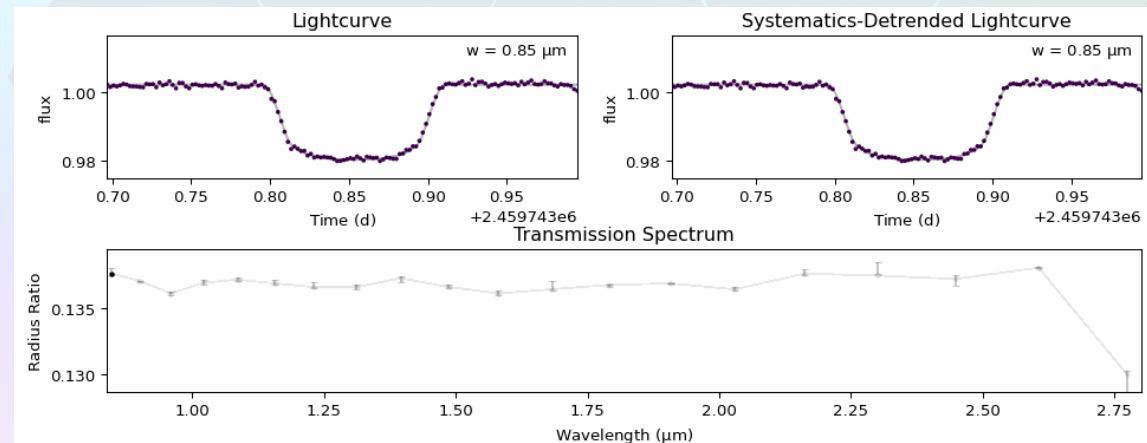
HAT-P-18b (directly from JWST Pipeline Stage 3)



Simulated Data



HAT-P-18b (directly from JWST Pipeline Stage 3)



In Summary...

The image shows three GitHub repository pages side-by-side:

- Top Repository:** `catrionamurray/chromatic_fitting` (Public). It has 8 issues and 1 pull request.
- Middle Repository:** `zkbt/chromatic` (Public). It has 16 issues and 1 pull request.
- Bottom Repository:** `chromatic/chromatic`. This page is the landing page for the `chromatic` package. It links to the `chromatic_fitting` documentation, which is currently active. The documentation page includes:
 - chromatic_fitting** package introduction.
 - Parameters**, **Tutorials**, and **Transit Fitting** sections.
 - A detailed description of the `chromatic_fitting` package, mentioning its use of `pymc3` and `exoplanet` for transit fits, and its ability to handle spectroscopic light curve data with polynomial or Gaussian Process models.
 - An explanation of the goal of `chromatic_fitting`, which is to facilitate fast, easy comparison of data reduction techniques by standardizing the light curve-fitting stage.

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