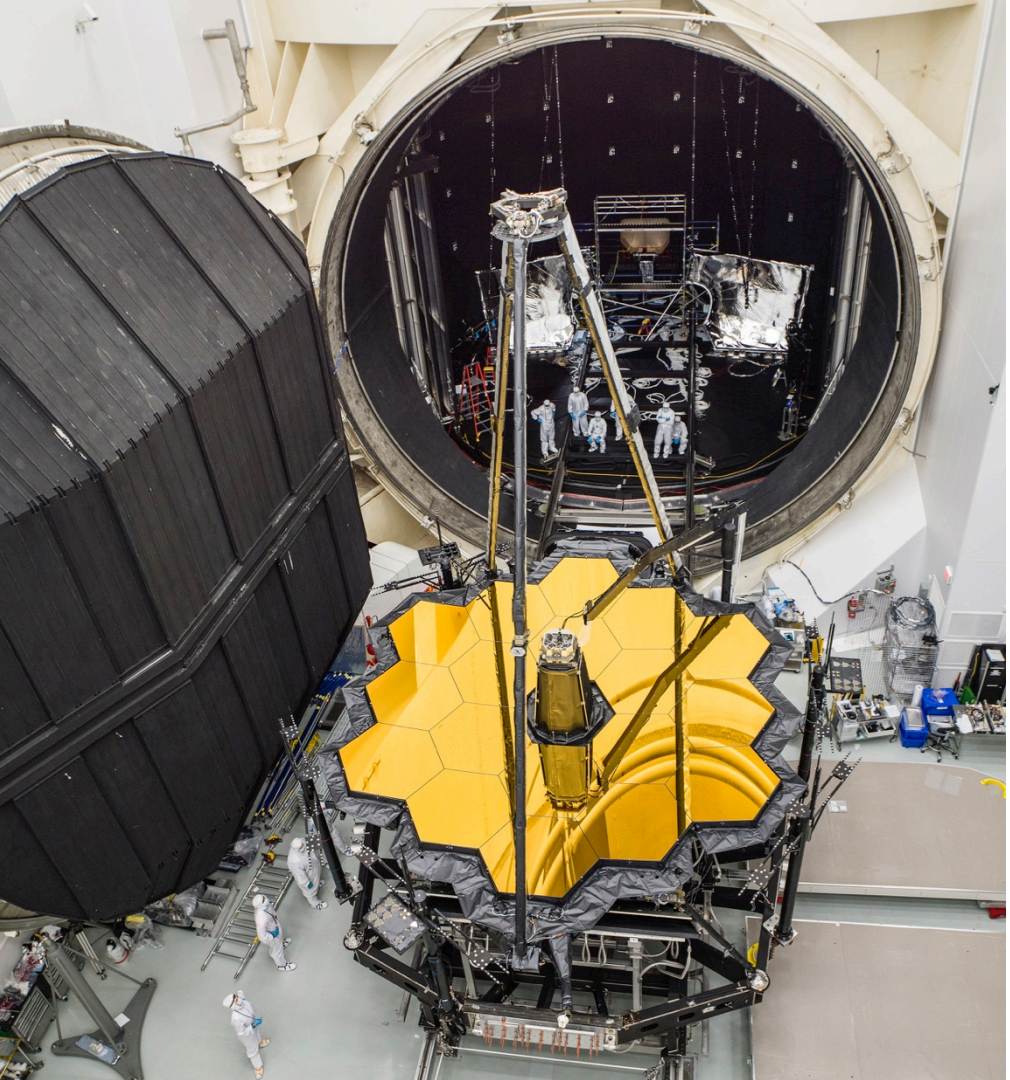

The Transiting Exoplanet Community Early Release Science Program for *JWST*

Jacob Bean
(University of Chicago)

On behalf of the transiting exoplanet ERS team

NASA @NASA · Jun 27

An independent review of @NASAWebb telescope that addresses a range of factors influencing schedule & performance is complete, unanimously recommending development of the telescope continue. We've established a new launch date of March 30, 2021. More: go.nasa.gov/2KpYuXi

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Replying to @NASA @NASAWebb

Let's be realistic and just say March of 20never.

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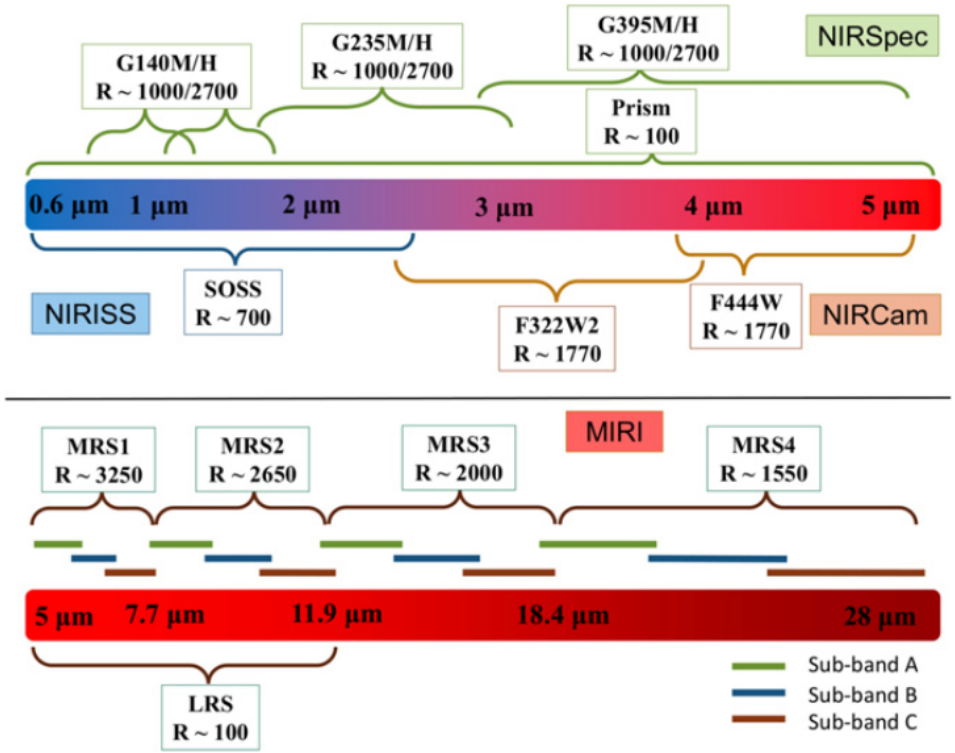
[redacted] Jun 27

Thanks to the many hundreds of people who continue to work towards *JWST* mission success!

JWST offers myriad instrument setup choices



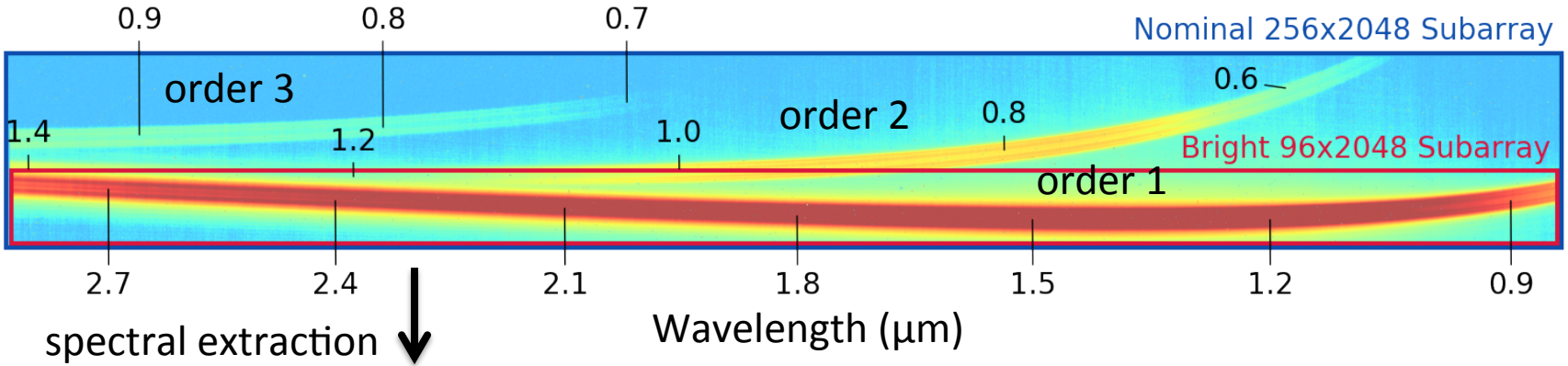
Stevenson+ 2016

Complications:

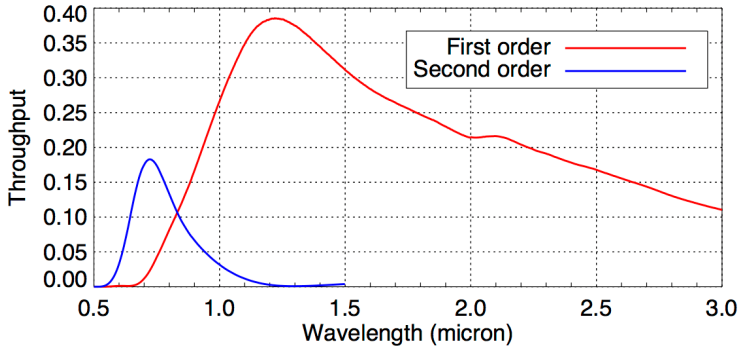
- entrance apertures
- pixel sampling
- bright limits
- spectral contamination
- throughput variations
- spatial profile variations
- detector gaps
- read patterns
- data limits
- observatory operations

JWST data reduction will be complex

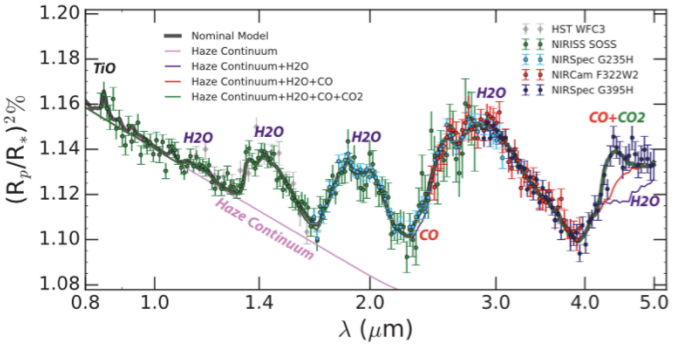
NIRISS + SOSS lab data



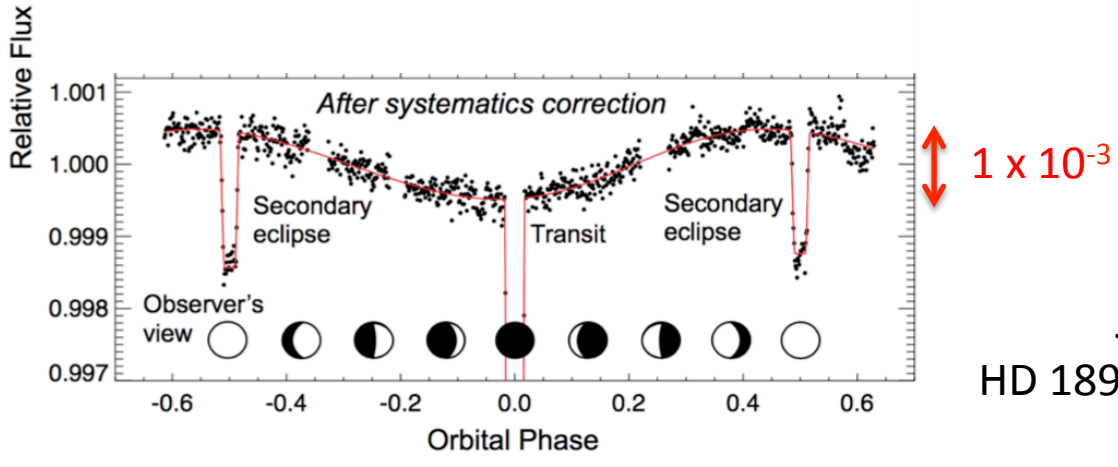
spectral extraction



Light curve modeling



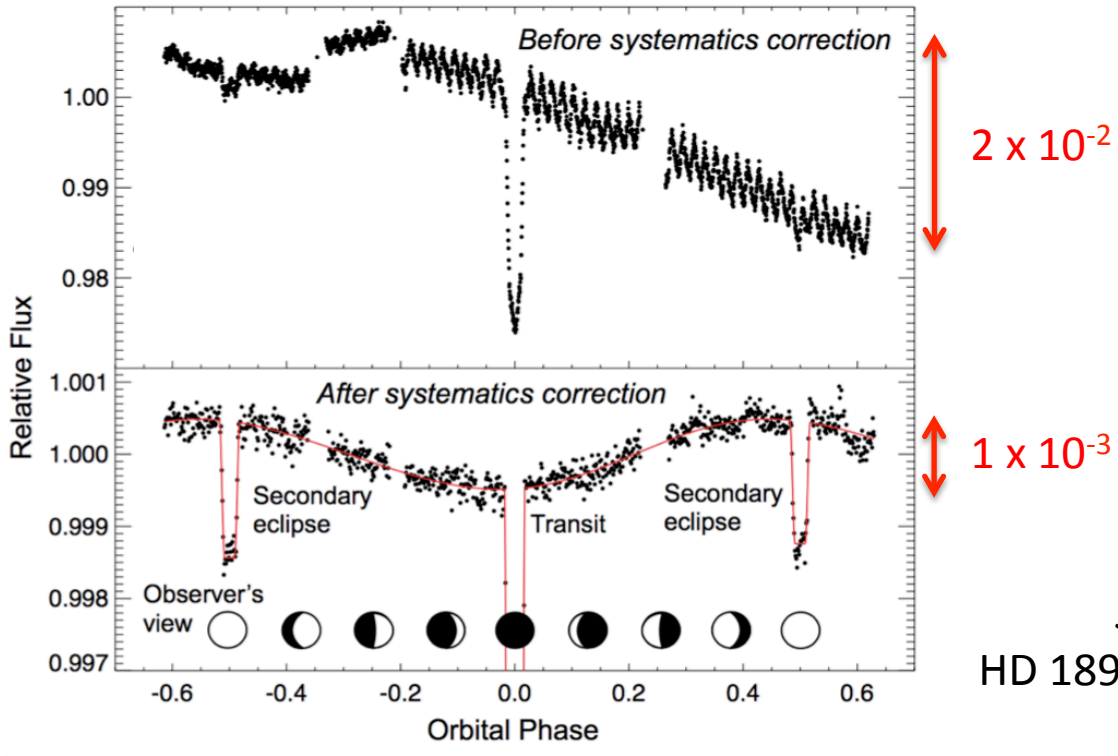
Robust correction of instrument systematics is essential



Spitzer/IRAC 4.5µm
HD 189733b thermal phase curve

Figure adapted from Knutson+ 2012

Robust correction of instrument systematics is essential



Spitzer/IRAC 4.5µm
HD 189733b thermal phase curve

Figure adapted from Knutson+ 2012

Goals of the transiting exoplanet community ERS program

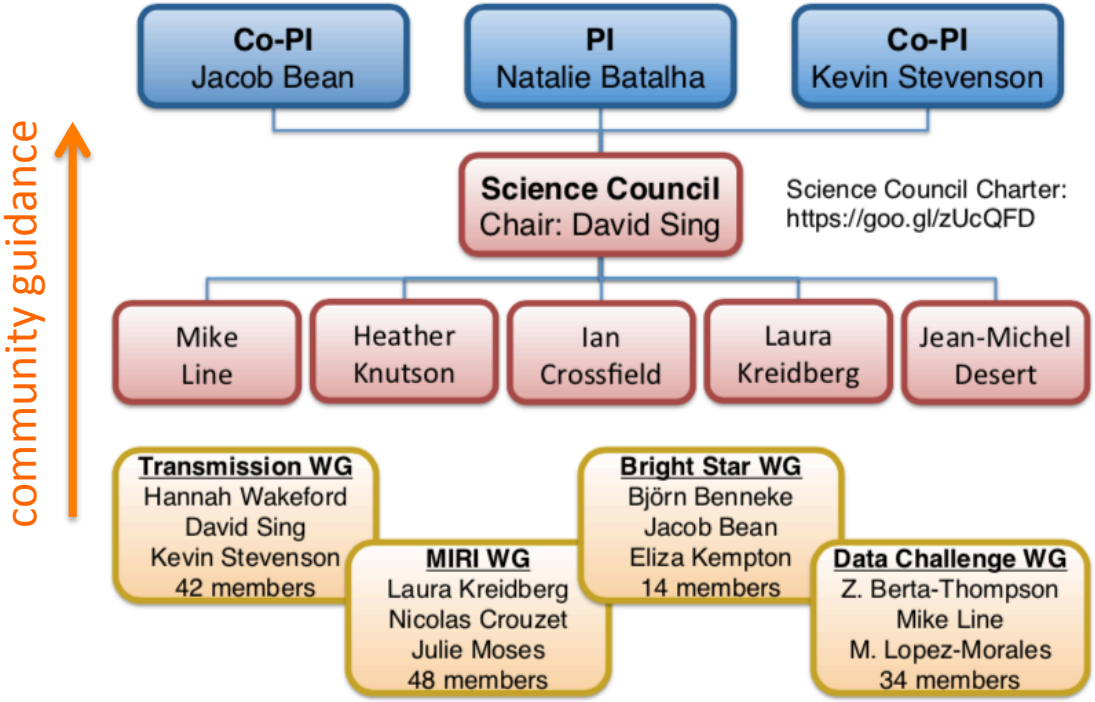
- Determine the spectrophotometric time-series performance of the key instrument modes on timescales relevant to transits for a representative range of target star brightnesses.

- Jump-start the process of developing remediation strategies for instrument-specific systematic noise.

- Provide the community a comprehensive suite of transiting exoplanet data to fully demonstrate *JWST*'s scientific capabilities in this area.

For more information see: Program 1377 information at STScI website
Bean+ 2018, PASP in revision, arXiv:1803.04985
https://ers-transit.github.io

Community



Currently 112 team members:

58% observers, 33% theorists

54% US, 46% EU + Canada

23% women overall

44% women in leadership roles

We welcome new team members!

ERS Program 1377: 80 hours of *JWST* time!

Panchromatic **Transmission**

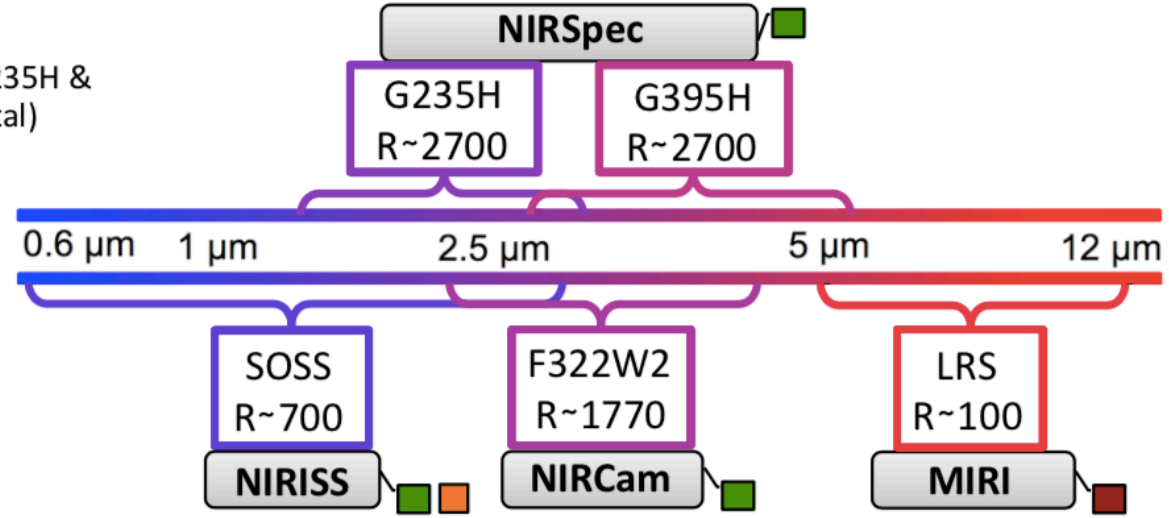
- nominal target: **WASP-79b**
- transits with NIRISS/SOSS, NIRSpec/G235H & G395H, and NIRCam/F322W2 (four total)

MIRI **Phase Curve**

- nominal target: **WASP-43b**
- one continuous, full-orbit observation covering two secondary eclipses and one transit with MIRI/LRS

Bright Star's Planet **Emission**

- nominal target: **WASP-18b**
- one secondary eclipse using NIRISS/SOSS

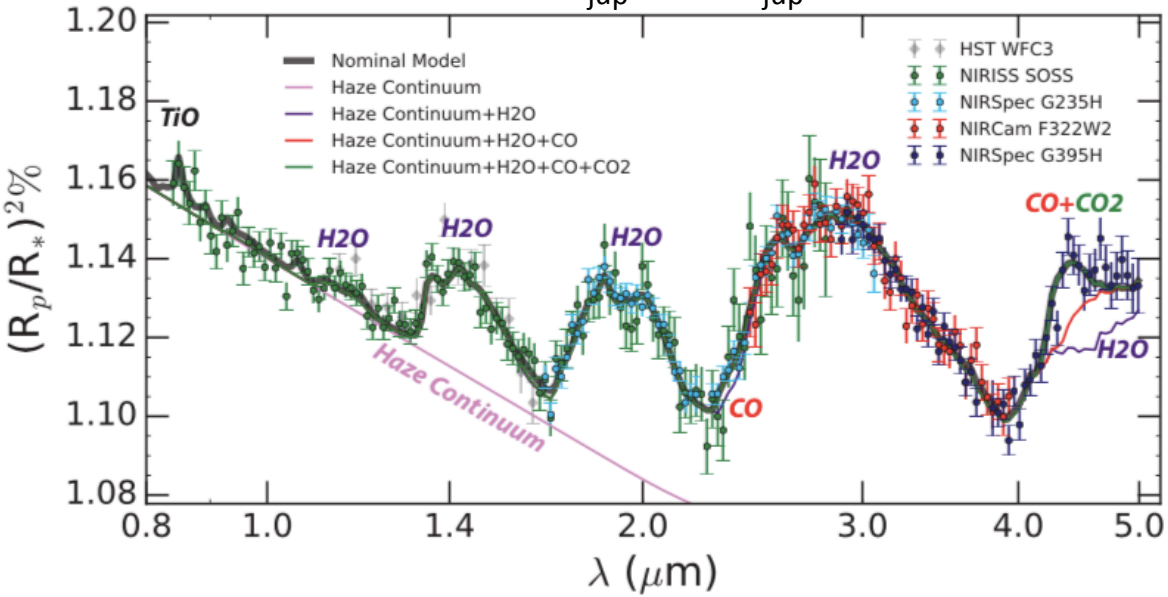


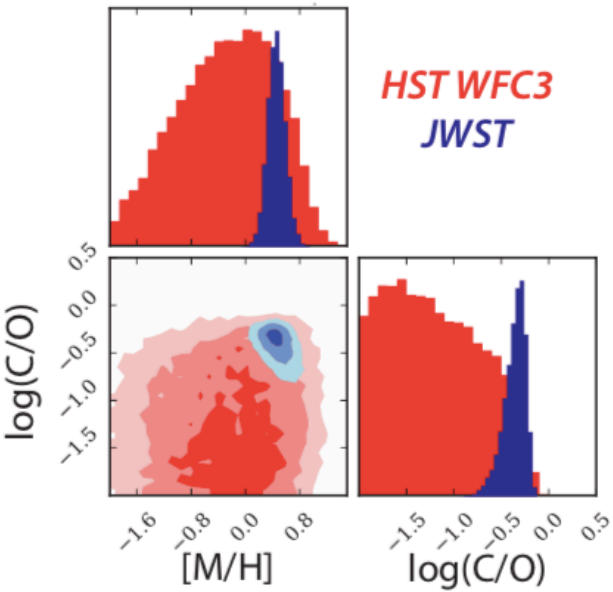
six observations, three planets, four instruments, three transiting planet geometries

1. Panchromatic transmission spectrum of a hot Jupiter

(NIRISS + NIRSpec + NIRCam: 0.6 – 5.0 μm, ~40 hrs)

WASP-79b: M=0.9 M_{jup}, R=2 R_{jup}, T=1750 K, J=9.3



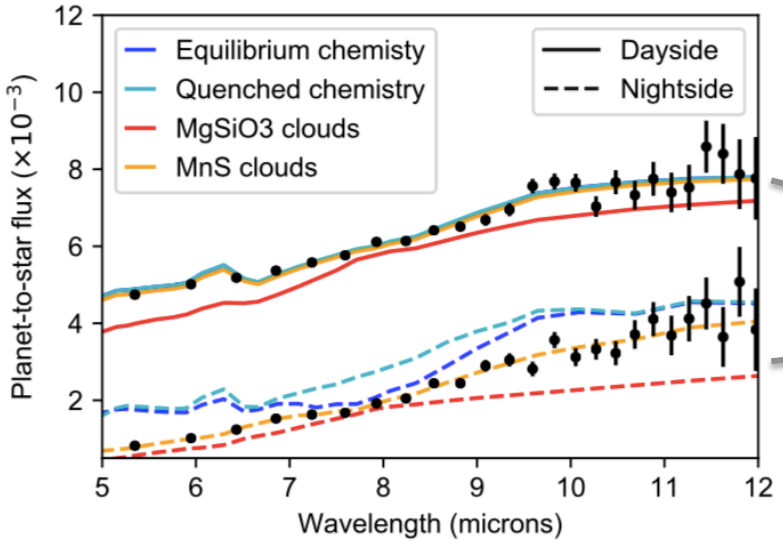


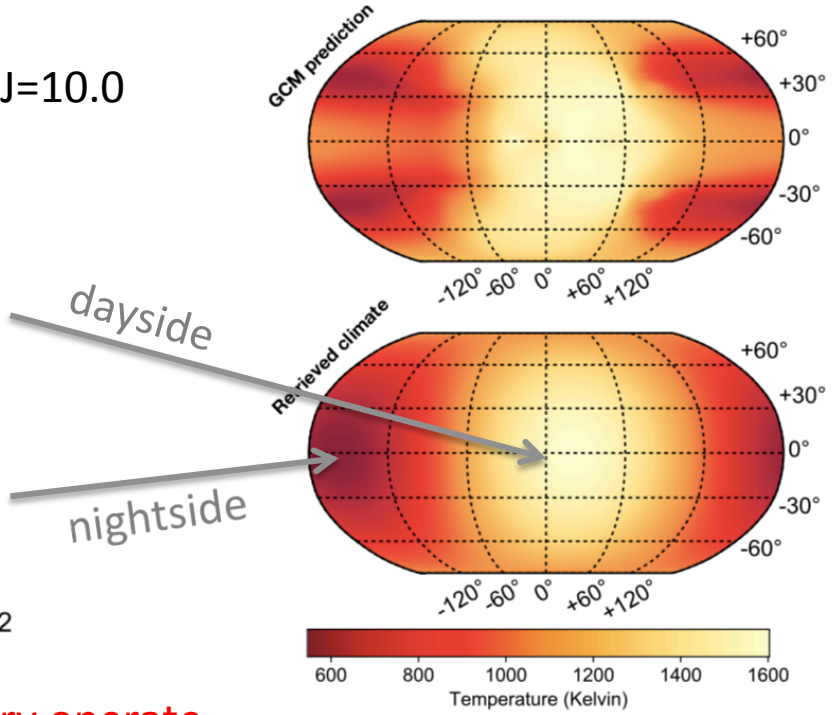
What is the chemical composition of a hot Jupiter?

HST data from Showalter+ in prep
see poster #45

2. Mid-infrared phase curve of a short-period hot Jupiter
(MIRI LRS: 5 − 12 µm, ~30 hrs)

WASP-43b: M=2 M_{jup}, R=1 R_{jup}, T=1450 K, J=10.0



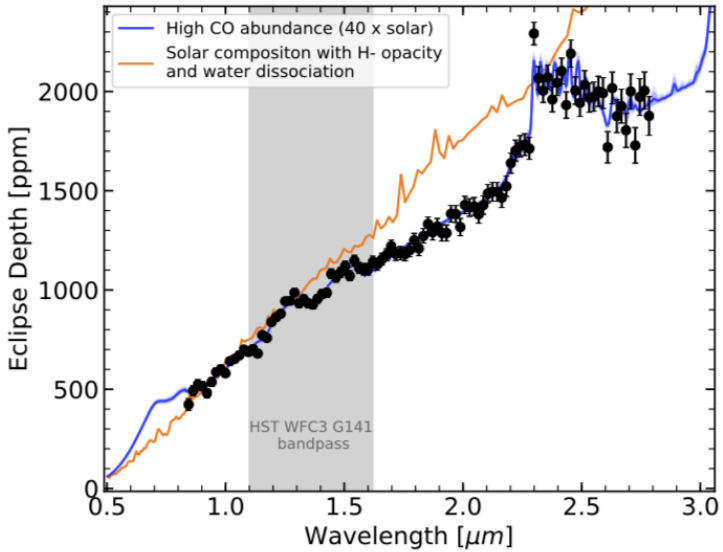


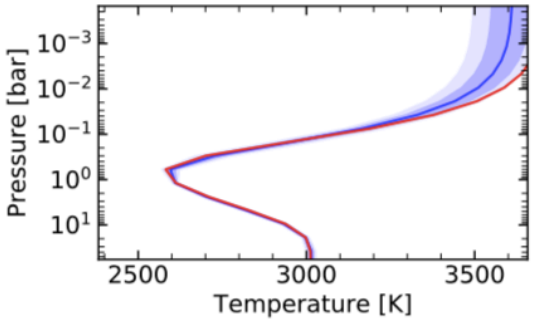
How does energy transport and 3D chemistry operate under extreme irradiation?

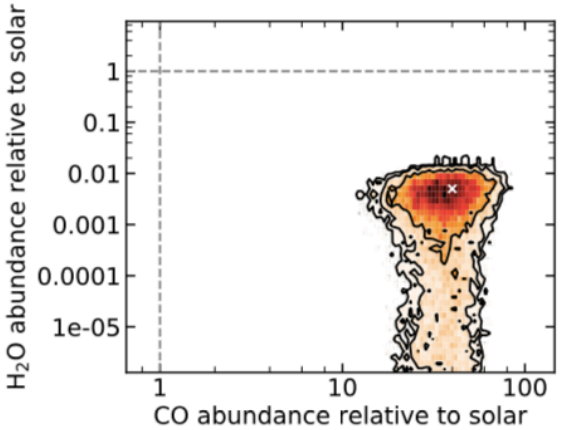
For more see Venot+ in prep

3. Thermal emission of a hot Jupiter orbiting a bright star
(NIRISS: 0.8 – 2.7 µm, ~10 hrs)

WASP-18b: M=10 M_{jup}, R=1.2 R_{jup}, T=2400 K, J=8.4





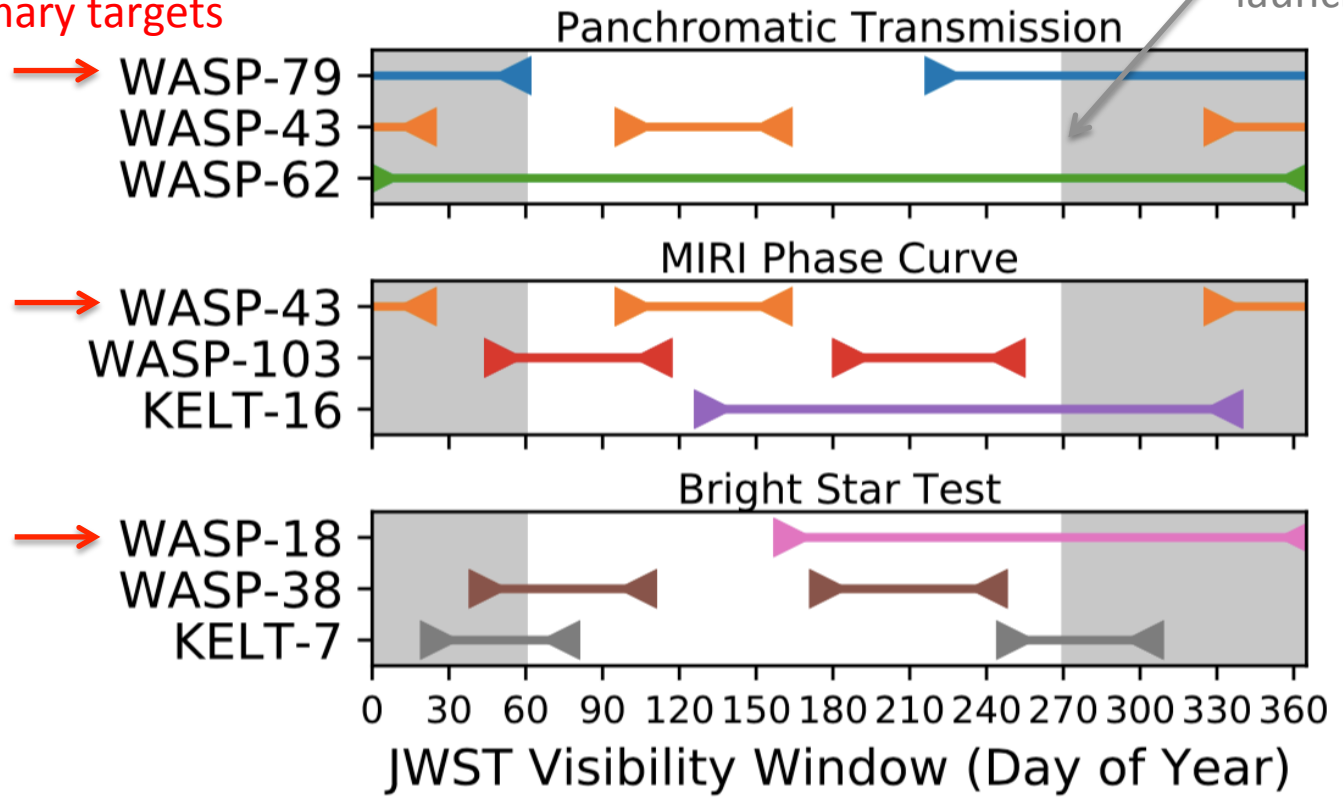


What is the chemistry, thermal structure, and energy budget of an ultra-hot Jupiter?

Target Selection

Start of *JWST* science assuming a March 30 launch

primary targets



We will host a JWST Exoplanet Data Challenge, including two workshops.

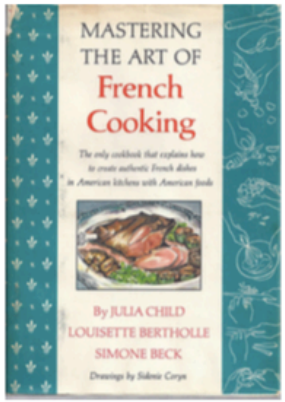
- **Before observations** — we will focus on simulated data, where we know the exact answers. We will meet to learn and develop analysis tools, and test the assumptions of different theoretical models and retrieval methods.

- **After observations** — we will focus on the real data, where we need cross-validation for robust results. We will meet to compare analyses and theoretical modeling frameworks, write papers, and produce science-enabling products.

These workshops will be open to the entire community, regardless of Co-I/Collaborator status on the proposal.

Science-Enabling Products

(1) Data Analysis Tutorials:



We will publish a worked example analysis of each JWST dataset (`jupyter` notebook), going from pixels to light curves and planetary spectra. These are **recipes** for future analyses.

Table 3. Core Ingredients for Data Analysis Toolkits

1	Visualize the time-series cube of 2D images, with static pixel-by-pixel mean and variance images and movies.
2	Extract 1D spectra and their predicted uncertainties, using both fixed apertures and optimal extractions. Measure time-series diagnostics that may inform instrumental models below.
3	Separate the instrumental and astrophysical signals, using physically-motivated causal models, as well as independent, statistical approaches such as Gaussian Process models and Principal/Independent Component Analysis techniques. Establish priors from our physical knowledge of the instrument.
4	Create a parameterized model of the planet feature that was observed (transit, eclipse, phase curve), including free parameters for stellar limb-darkening and stellar variability. Establish priors from our knowledge of the exoplanet system.
5	Fit this joint model to data, using MCMC or nested sampling to estimate the parameters' posterior probability distribution.
6	Extract the planetary spectra that are embedded within those fits, after marginalizing over all other parameters and possible instrumental models. These spectra constitute the core scientific measurements of the program, to be archived on MAST.

Slide courtesy Zach Berta-Thompson

Science-Enabling Products

(2) Instrument Performance Reports:

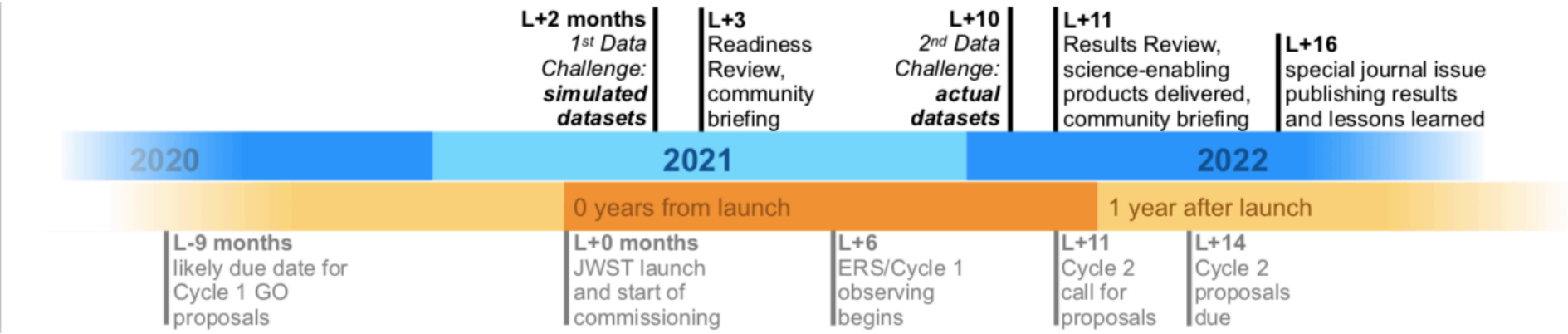
We will publish a report (`jupyter` notebook) documenting the systematics seen in each JWST instrument. These are **field guides** for what future observers should know.

Table 4. Basic Outline of Instrument Performance Reports

The field guides will measure diagnostics...	**...to help answer basic questions about the instrument.**
• the number of photons detected per wavelength	Are `PandExo`/`Pandeia`'s core throughput estimates and instrument models accurate?
• the measured variance of the flux residuals compared to photon noise predictions • tests for non-Gaussianity of the flux residuals	Is the spectrophotometry photon-limited, or are there other significant time-series noise sources?
• the measured variance of time-binned flux residuals vs. temporal bin size • the power spectrum and autocorrelation function of the flux residuals	Is the noise correlated in time? How will this limit JWST's precision for exoplanet observables?
• the position/width/shape of the spectral trace vs. time • the background level and reference pixel values vs. time	How stable are the telescope/instrument optics and detectors over hours-to-days timescales?
• the strength and form of correlations between the residuals and other available time series (the above image diagnostics, temperature sensors, telescope pointing, antenna movements)	What physically-motivated models might explain systematic noise in time-series measurements?
• the measured variance of wavelength-binned residuals vs. wavelength bin size • a matrix of correlation strength between all possible wavelength bins	What instrumental systematics are "common-mode"? How well can we separate overlapping wavelengths?
• the descriptive morphology of any other time-dependent trends in the measured spectrophotometry	What is the timescale of detector persistence/charge-trapping? How long does *JWST* need to settle at the start of an observation?

Slide courtesy Zach Berta-Thompson

Timeline


L+2 months
1st Data Challenge: simulated datasets
L+3
Readiness Review, community briefing
L+10
2nd Data Challenge: actual datasets
L+11
Results Review, science-enabling products delivered, community briefing
L+16
special journal issue publishing results and lessons learned
2020
2021
2022
0 years from launch
1 year after launch
L-9 months
likely due date for Cycle 1 GO proposals
L+0 months
JWST launch and start of commissioning
L+6
ERS/Cycle 1 observing begins
L+11
Cycle 2 call for proposals
L+14
Cycle 2 proposals due

Timeline

L+2 months
1st Data Challenge: ***simulated datasets***

2020

0 years from

L-9 months
likely due date for Cycle 1 GO proposals

L+0 months
JWST launch and start of commissioning

TESS 2 year mission complete

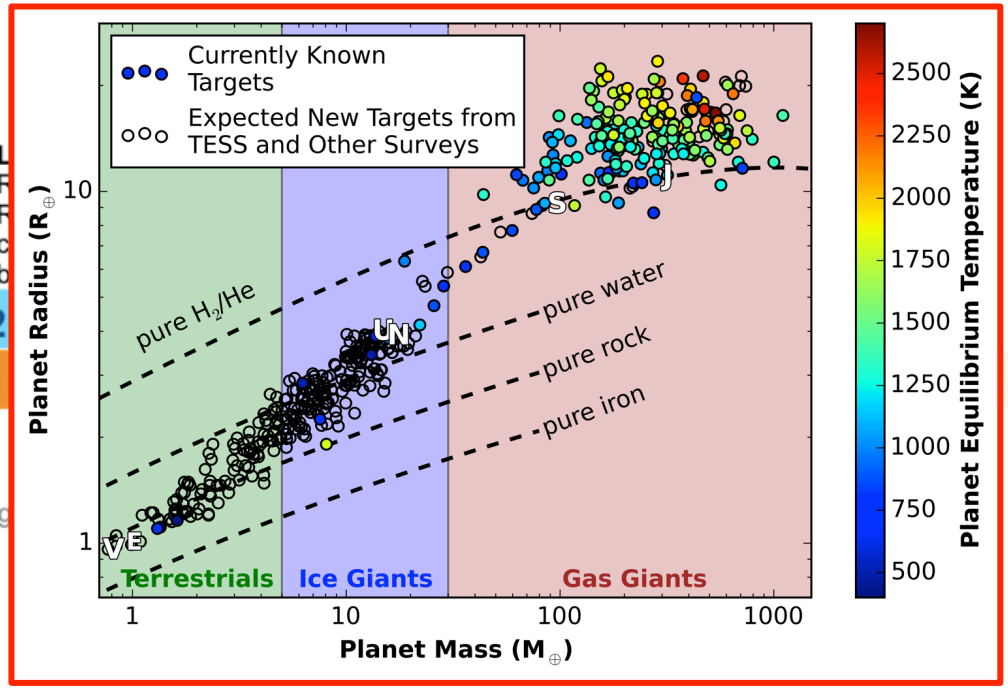
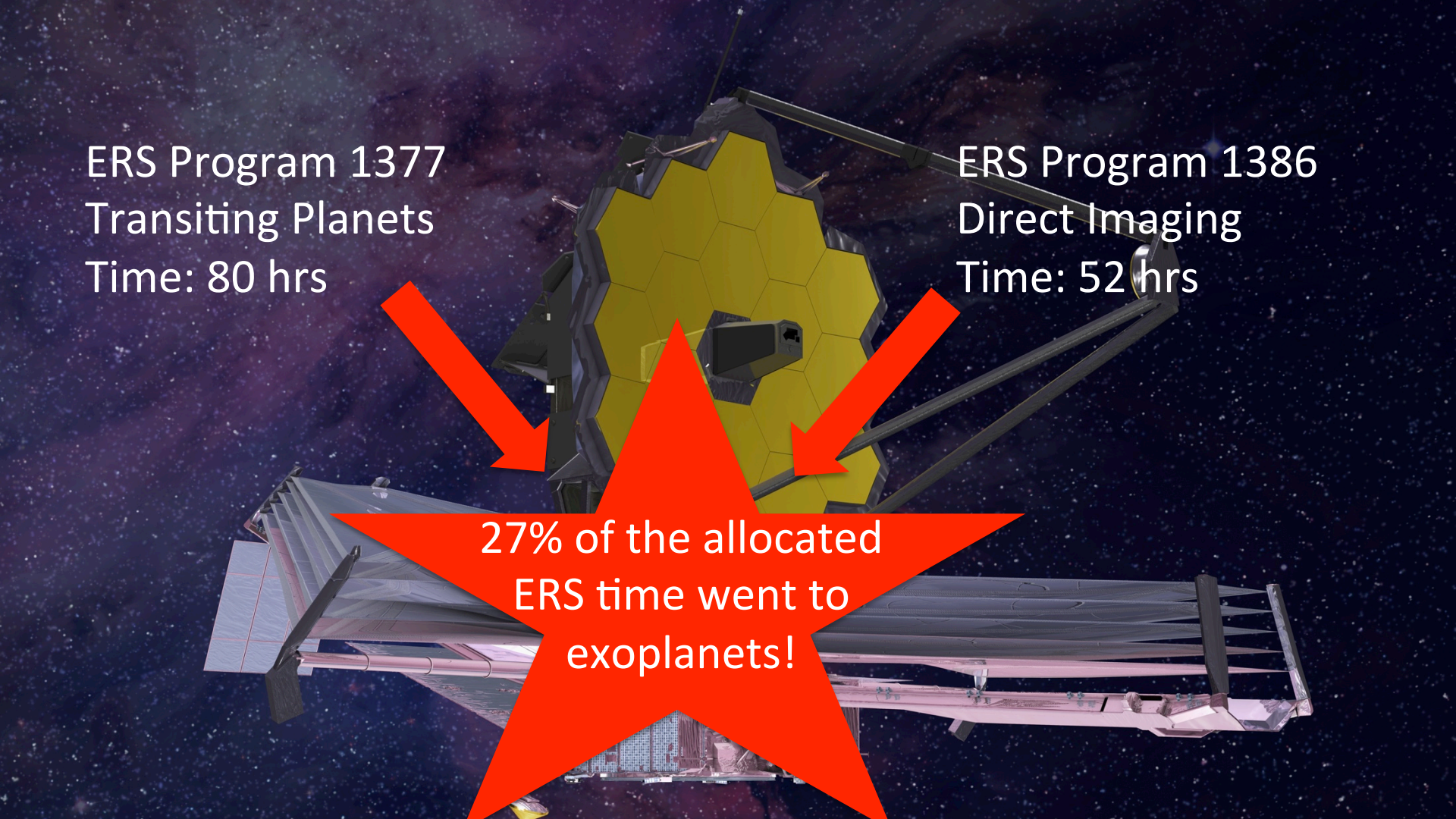


Figure from Rob Zellem
See also: Kempton+ 2018 (arXiv:1805.03671)

ERS Program 1377
Transiting Planets
Time: 80 hrs

ERS Program 1386
Direct Imaging
Time: 52 hrs

(see Hinkley talk tomorrow morning)


ERS Program 1377
Transiting Planets
Time: 80 hrs
ERS Program 1386
Direct Imaging
Time: 52 hrs
27% of the allocated
ERS time went to
exoplanets!