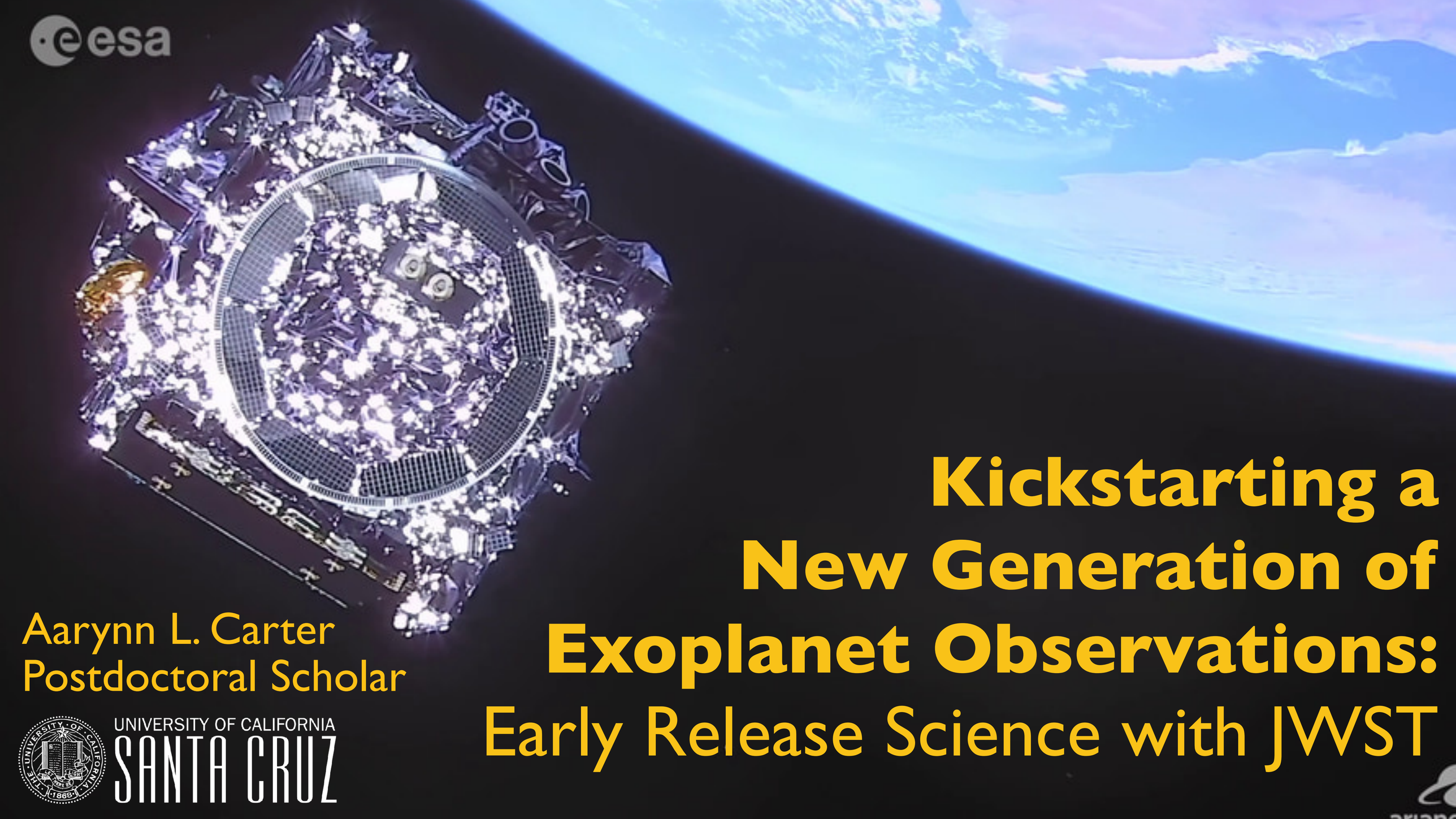

# Kickstarting a New Generation of Exoplanet Observations: Early Release Science with JWST

Aarynn L. Carter
Postdoctoral Scholar
UNIVERSITY OF CALIFORNIA SANTA CRUZ

# The Transiting Exoplanet ERS Team

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Benneke Björn
Berta-Thompson Zachory K.
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de Wit Julien
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Espinoza Nestor
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García Muñoz Antonio
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Ingalls James G.
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Redfield Seth
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Rocchetto Marco
Rogers Leslie A.
Roudier Gaël
Schlawin Everett
Shkolnik Evgenya L.
Showman Adam P.
Sing David K.
Southworth John
Spake Jessica J.
Stevenson Kevin B.
Swain Mark R.
Teske Johanna C.
Todorov Kamen O.
Tremblin Pascal
Tsiaras Angelos
Tucker Gregory S.
Venot Olivia
Waalkes William C.
Wakeford Hannah R.
Waldmann Ingo P.
Weaver Ian
Wheatley Peter J.
Zellem Robert T.
YOUR NAME HERE

# The High Contrast Exoplanet ERS Team

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Mickael Bonnefoy
Brendan Bowler
Aarynn Carter
Christine Chen
Elodie Choquet
Thayne Currie
Camilla Danielski
Jonathan Fortney
Carol Grady
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Dean Hines
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Paul Kalas
Grant Kennedy
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Anne-Marie Lagrange
Mike Liu
Mark Marley
Christian Marois
Brenda Matthews
Dimitri Mawet
Stan Metchev
Michael Meyer
Max Millar-Blanchaer
Marshall Perrin
Laurent Pueyo
Sascha Quanz
Julien Rameau
T.J. Rodigas
Stephanie Sallum
Beth Sargent
Josh Schlieder
Glenn Schneider
Karl Stapelfeldt
Pascal Tremblin
Arthur Vigan
Marie Ygouf
Olivier Absil
Suzanne Aigrain
Jo Barstow
Jean-Loup Baudino
Russ Belikov
Gordy Bjoraker
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Mariangela Bonavita
Mark Booth
Jeroen Bouwman
Wolfgang Brandner
Zack Briesemeister
Marta Bryan
Faustine Cantalloube
Ludmila Carone
Benjamin Charnay
Gael Chauvin
Anthony Cheetham
Valentin Christiaens
Ian Crossfield
John Debes
Zach Draper
Trent DuPuy
Sam Factor
Romain Falla
Markus Feldt
Mike Fitzgerald
Ryan Garland
Thomas Henning
Michael Ireland
Patrick Irwin
Hannah Jang-Condell
Theodora Karalidi
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Pierre Kervella
Hubert Klahr
John Krist
Masayuki Kuzuhara
Pierre-Olivier Lagage
Ralf Launhardt
Jean-Francois Lestrade
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Frantz Martinache
Raquel Martinez
Elisabeth Matthews
Nathan Mayne
Johan Mazoyer
Mike McElwain
Tiffany Meshkat
Brittany Miles
Farisa Morales
Katie Morzinkski
David Mouillet
Andre Muller
Mamadou N'Diaye
Deborah Padgett
Eric Pantin
Andreas Quirrenbach
Abhijith Rajan
Maxime Rizzo
Laetitia Rodet
Johannes Sahlmann
Matthias Samland
David Sing
Anand Sivaramakrishnan
Frans Snik
Jordan Stone
Motohide Tamura
Niranjan Thatte
Peter Tuthill
Roy van Boekel
Olivia Venot
Johanna Vos
Jason Wang
Ji Wang
John Wisniewski
Mark Wyatt
Neil Zimmerman

+ You?

Introduction to JWST ERS

Transiting Exoplanet ERS Program

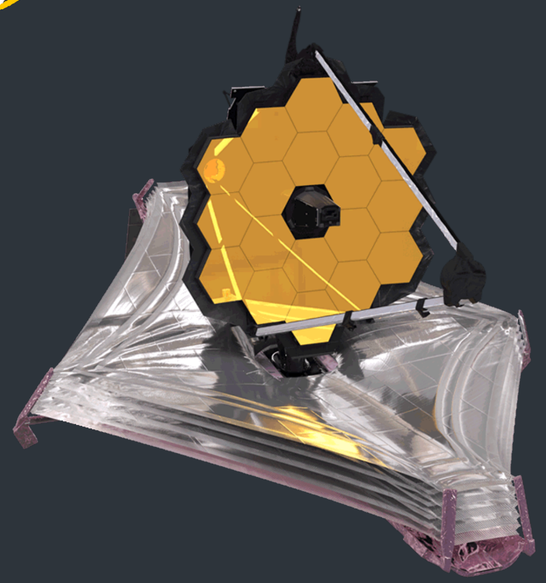
Direct Imaging Exoplanet ERS Program

What's In A Name?

Conclusions

Disequilibrium Chemistry

Biosignatures



Cloud Physics and Chemistry

Exoplanet Discoveries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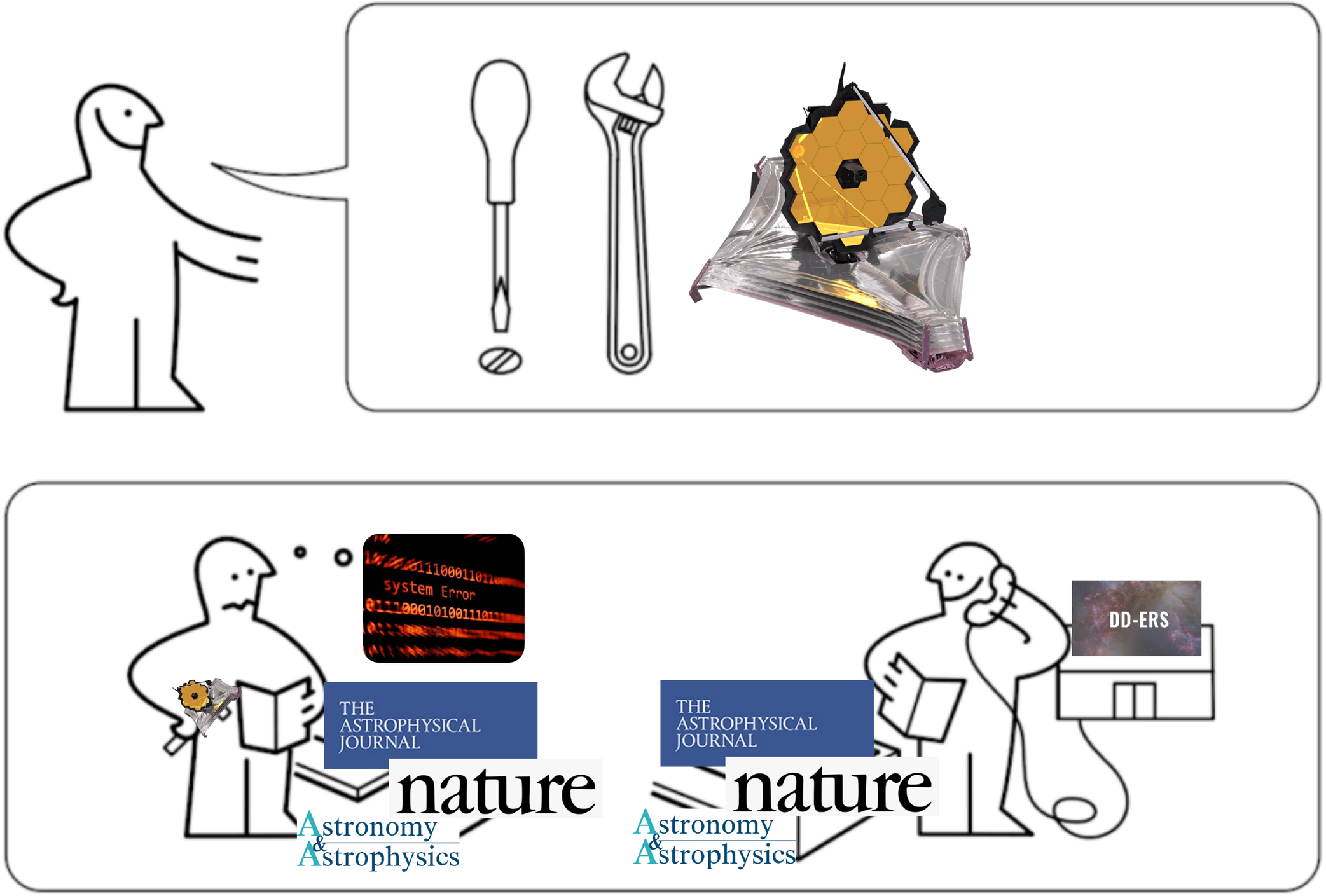
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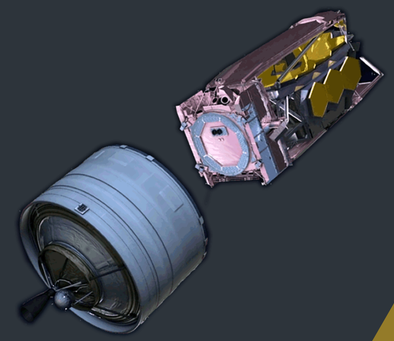

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Direct Imaging Exoplanet ERS Program

What's In A Name?

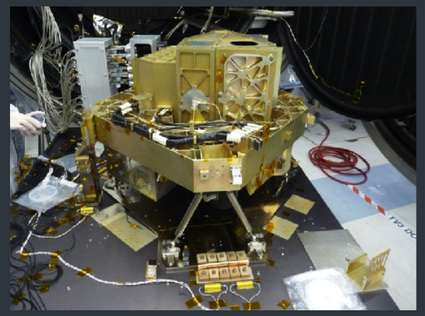
Conclusions

# The Goals of the Program

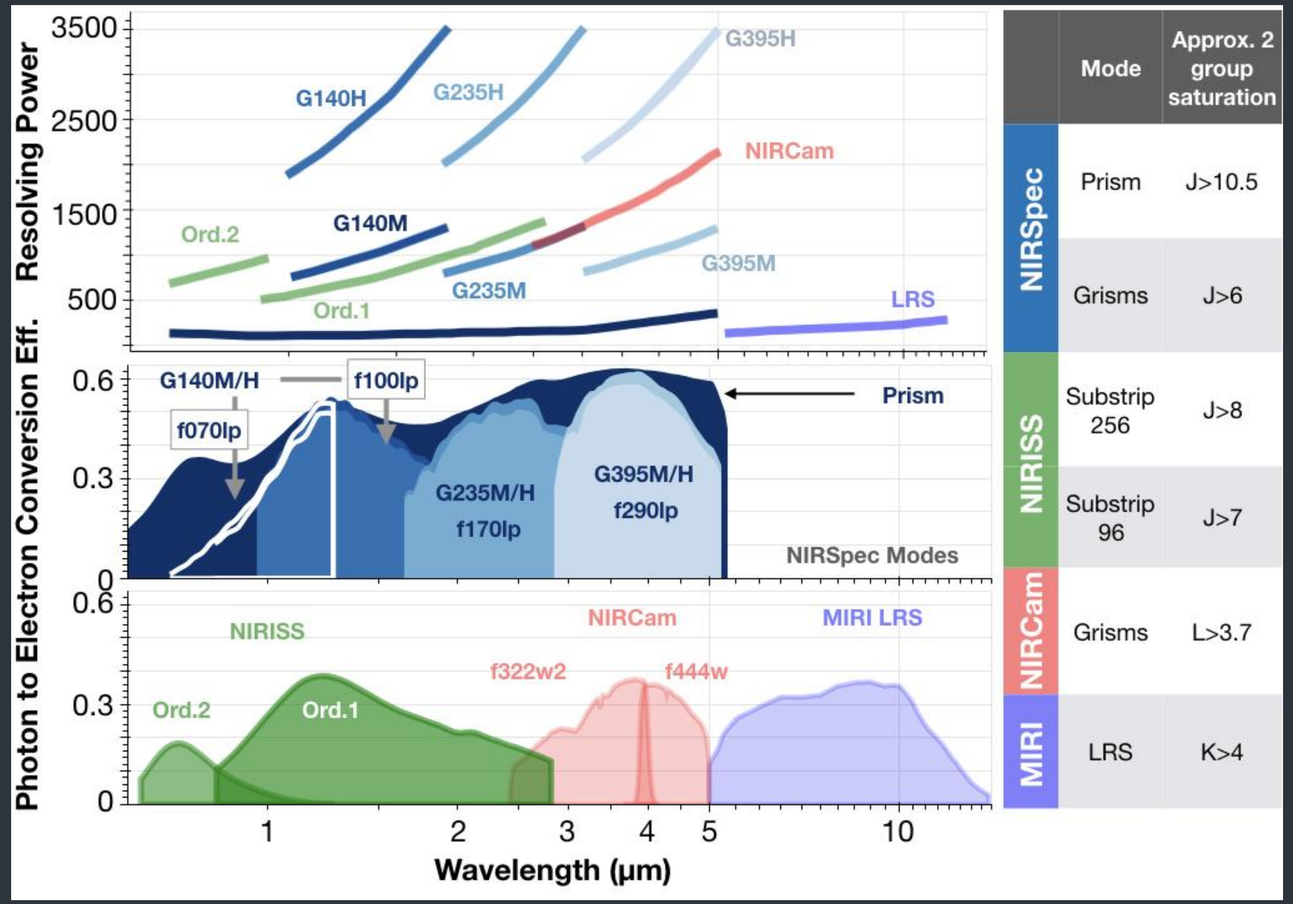
# The Goals of the Program

- Test all spectroscopic time series observing modes

## NIRISS

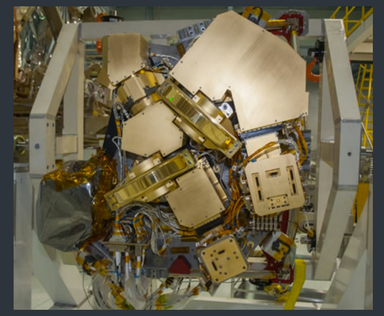


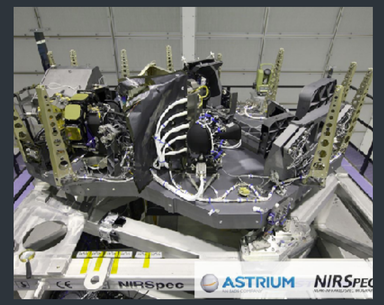
## MIRI




| | Mode | Approx. 2 group saturation |
|---|---|---|
| NIRSpec | Prism | J>10.5 |
| | Grisms | J>6 |
| NIRISS | Substrip 256 | J>8 |
| | Substrip 96 | J>7 |
| NIRCam | Grisms | L>3.7 |
| MIRI | LRS | K>4 |

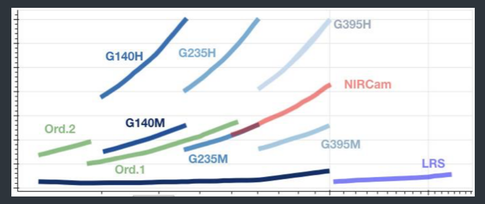
## NIRCam






## NIRSpec

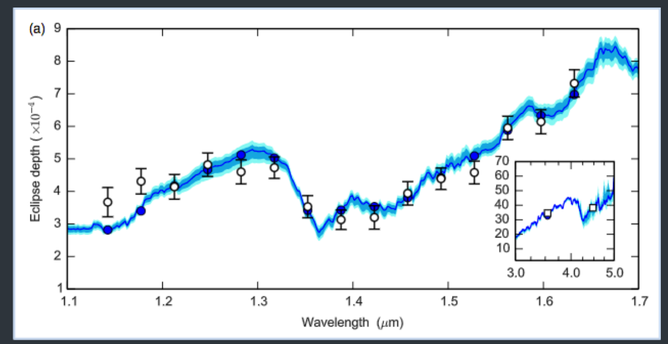
# The Goals of the Program

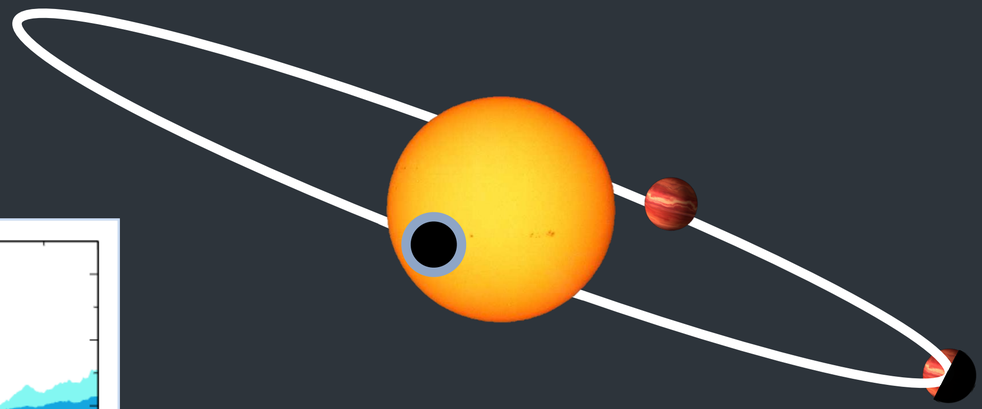



- Test all spectroscopic time series observing modes

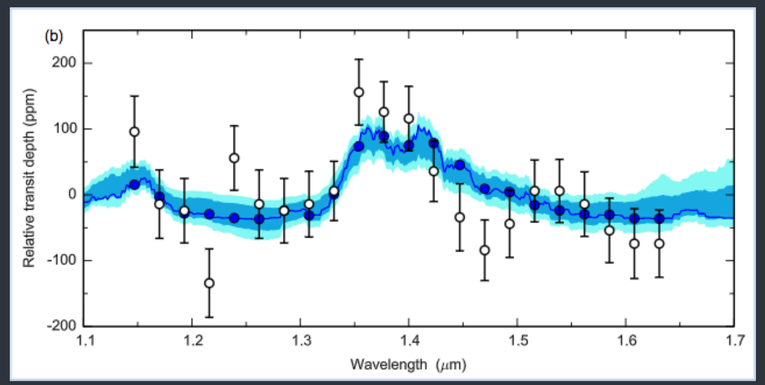
- Observe all transiting planet phenomena

Emission

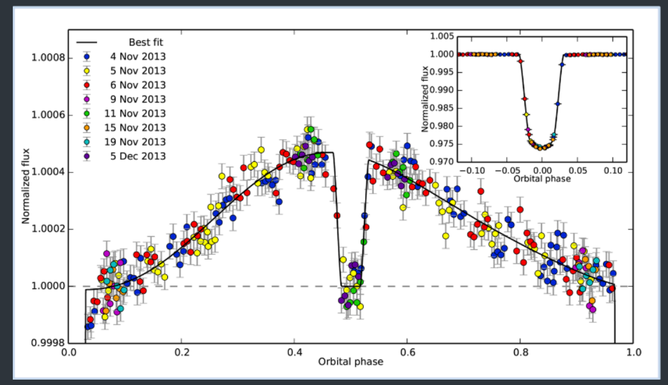


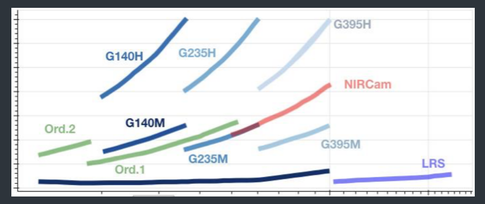
Transmission




Phase Curve Modulations

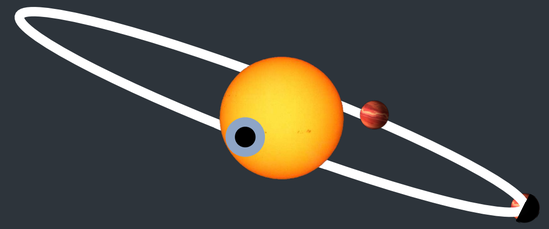


# The Goals of the Program



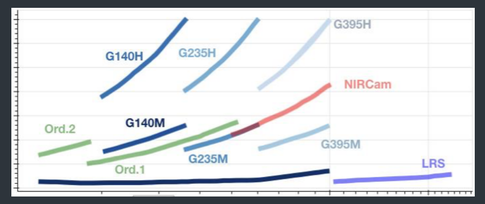

- Test all spectroscopic time series observing modes

- Observe all transiting planet phenomena



- Target benchmark exoplanets

# The Goals of the Program

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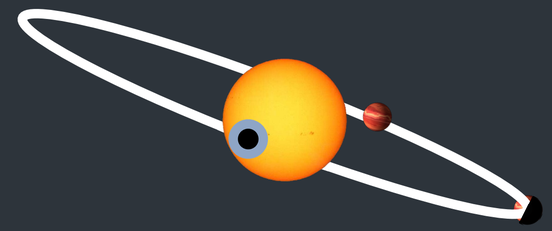
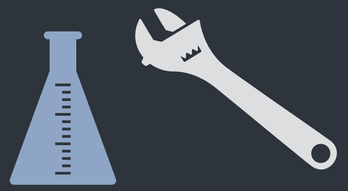


- Target benchmark exoplanets

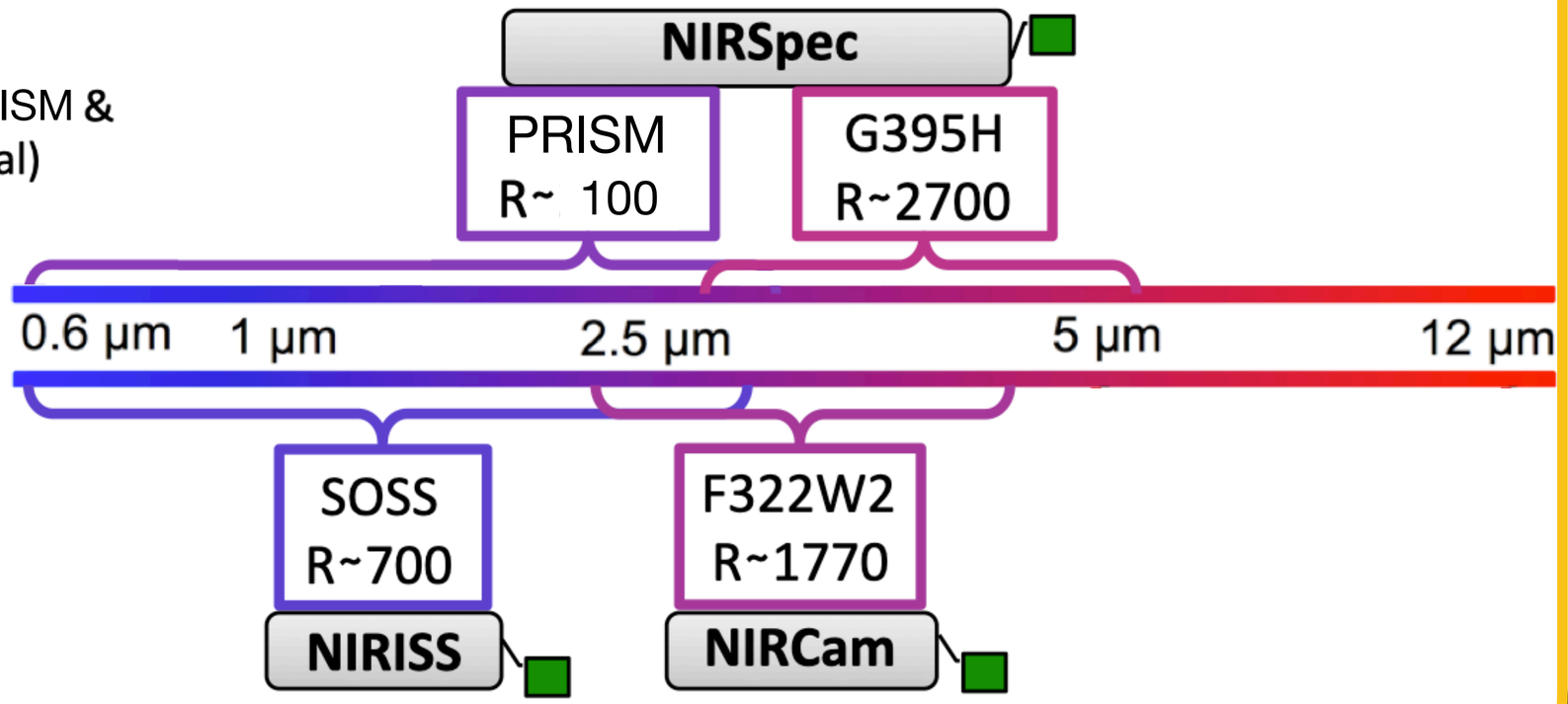
- Enable diverse science beyond the ERS program



# Three Targets Across Three Different Programs

## Panchromatic **Transmission**

- nominal target: **WASP-39b**
- transits with NIRISS/SOSS, NIRSpec/PRISM & G395H, and NIRCam/F322W2 (four total)



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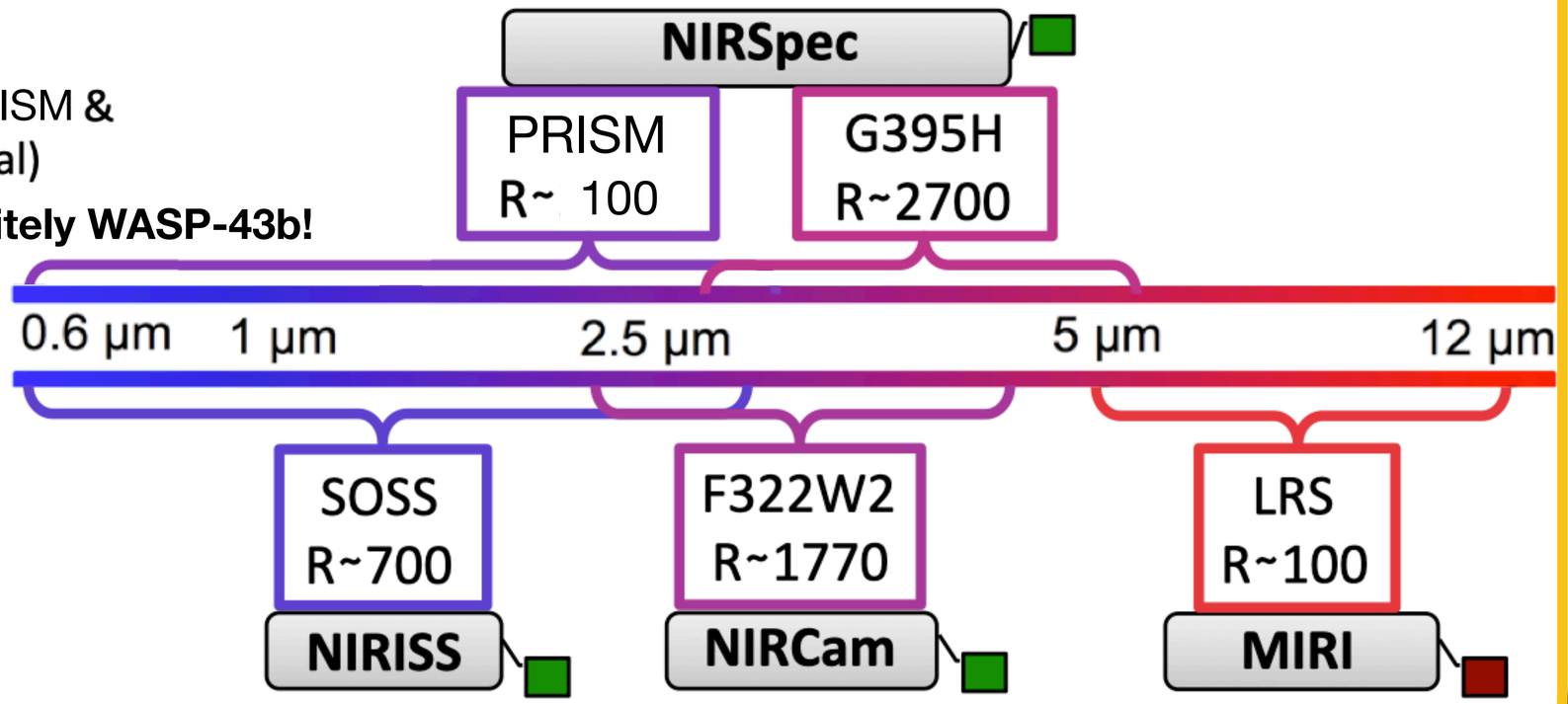
## MIRI Phase Curve

~~WASP-18b~~ **Definitely WASP-43b!**

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



# Three Targets Across Three Different Programs

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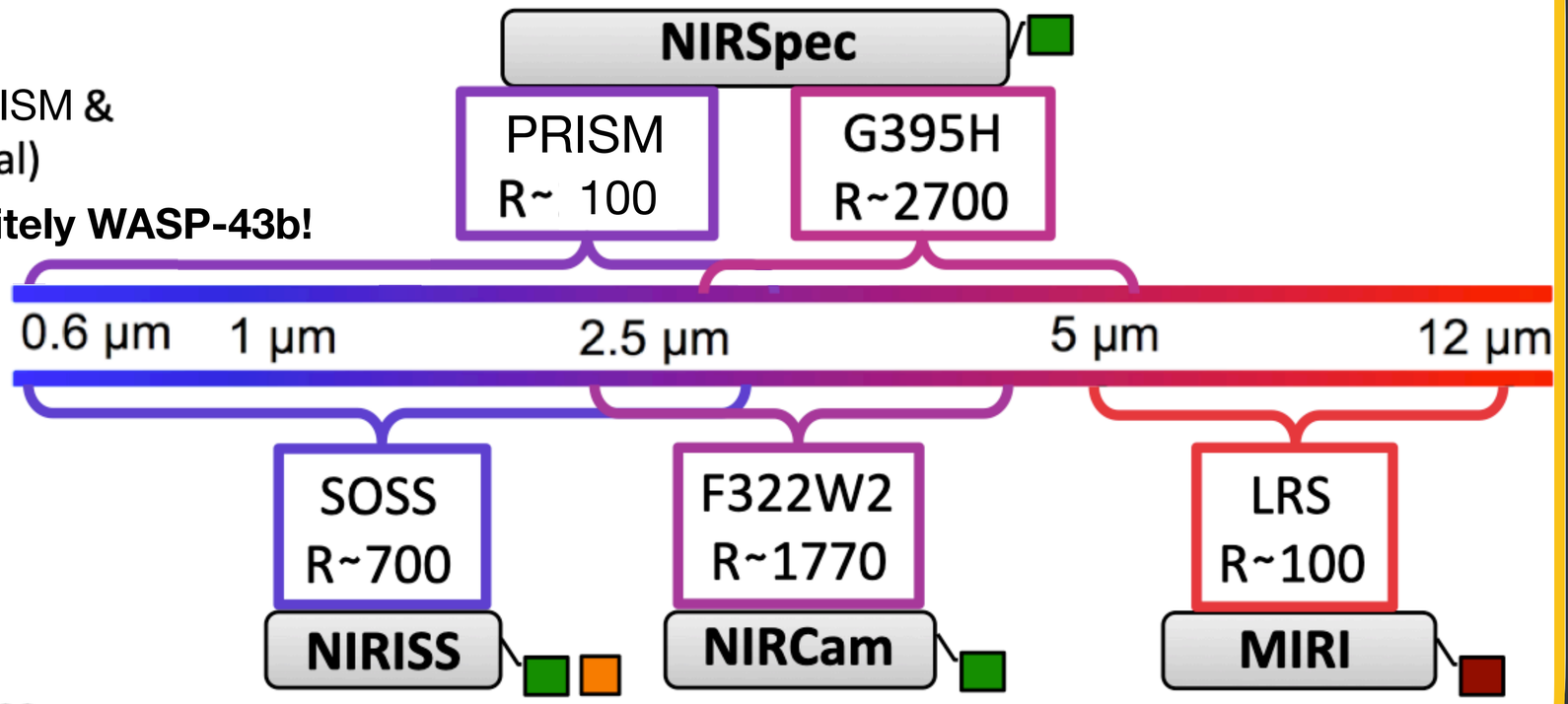
## MIRI Phase Curve

~~WASP-18b~~ **Definitely WASP-43b!**

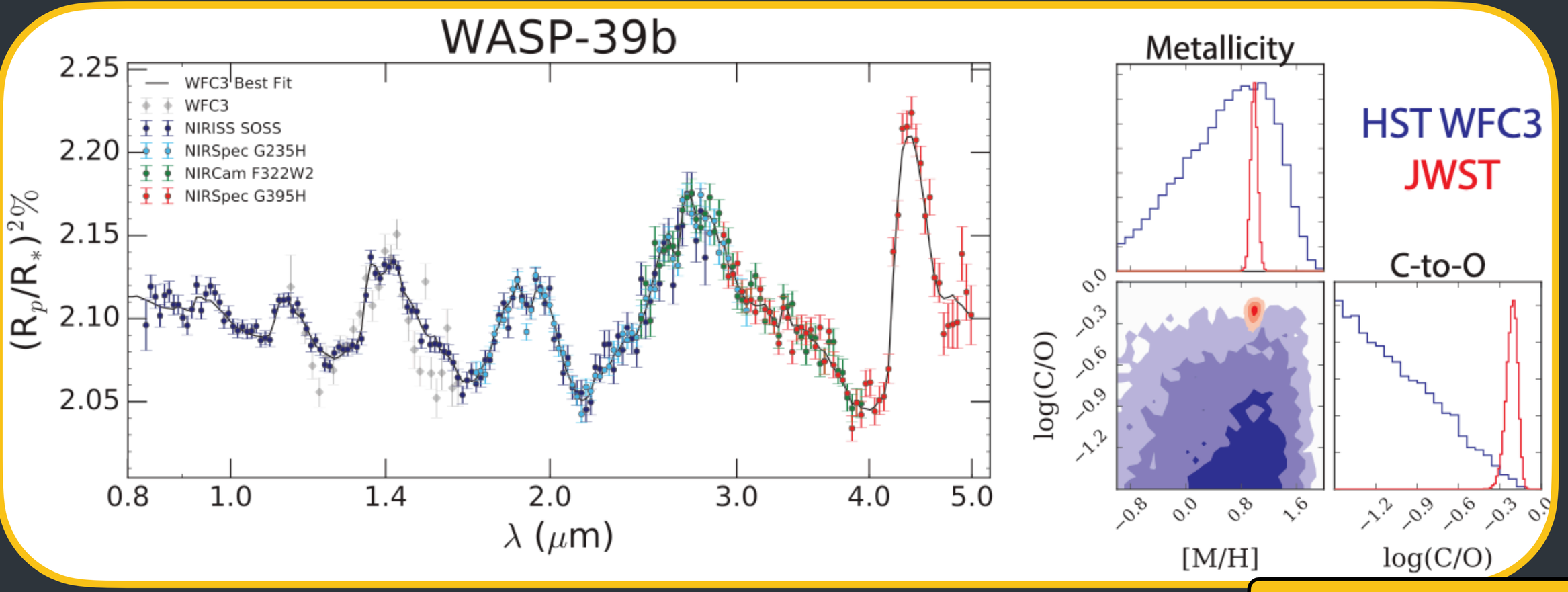
- nominal target: ~~WASP-43b~~
- one continuous, full-orbit observation covering two secondary eclipses and one transit with MIRI/LRS

## Bright Star's Planet Emission

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



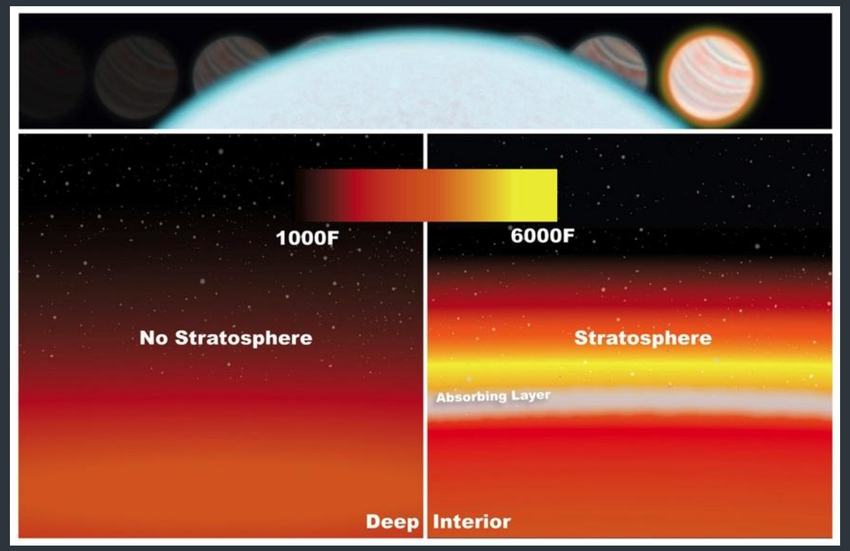
# Precision & Wavelength Coverage Offers Transformational Capabilities



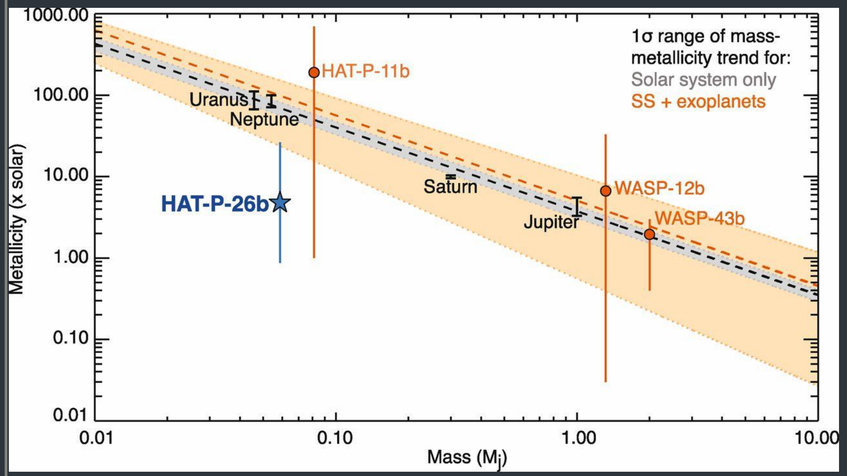

Hannah Wakeford, @stellarplanet

# Example Science Drivers

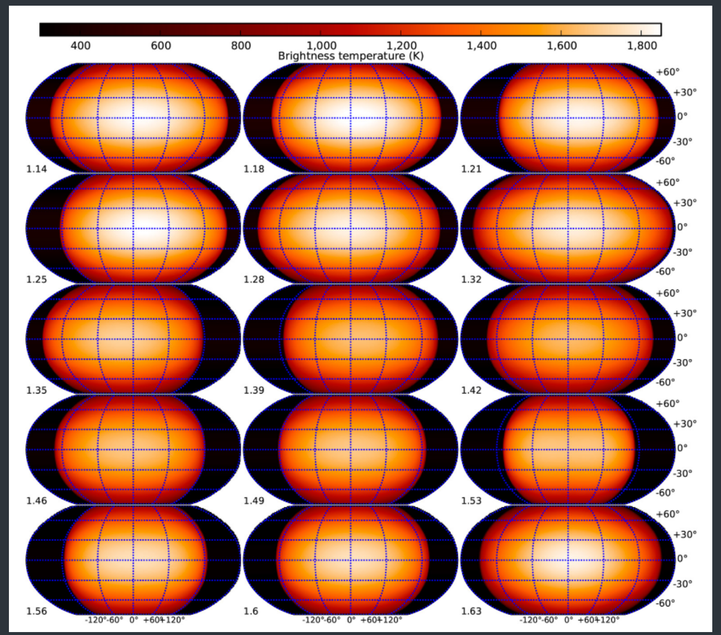
Molecular Abundances, C/O, Metallicity




Longitudinal Mapping, Climate




Temperature-Pressure Profiles



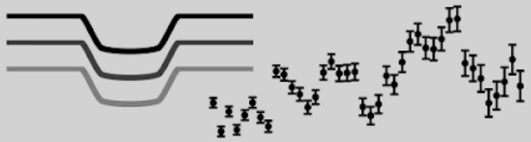
# Community Support is Already Ongoing!

# Simulated Data is Publicly Available

| Instrument | POC | Signal | Red Noise | Stage 0 | Stage 1 Outputs | Stage 2 Outputs | Stage 3 Outputs |
|---|---|---|---|---|---|---|---|
| NIRSpec | D. Sing, A. Carter CV3 Test Data | WASP-39b Transit | ✗ | ✗ | ✓ | ✓ | ✗ |
| NIRCam | E. Schlawin T. Beatty | WASP-39b Transit | ✓ | ✓ | ✓ | ✓ | ✓ |
| NIRISS | N. Espinoza | WASP-39b Transit | ✗ | ✓ | ✓ | ✓ | ✗ |
| MIRI | P. Olivier-Lagage A. Dyrek | NGTS-10b Phase Curve | ✗ | ✓ | ✓ | ✓ | ✗ |

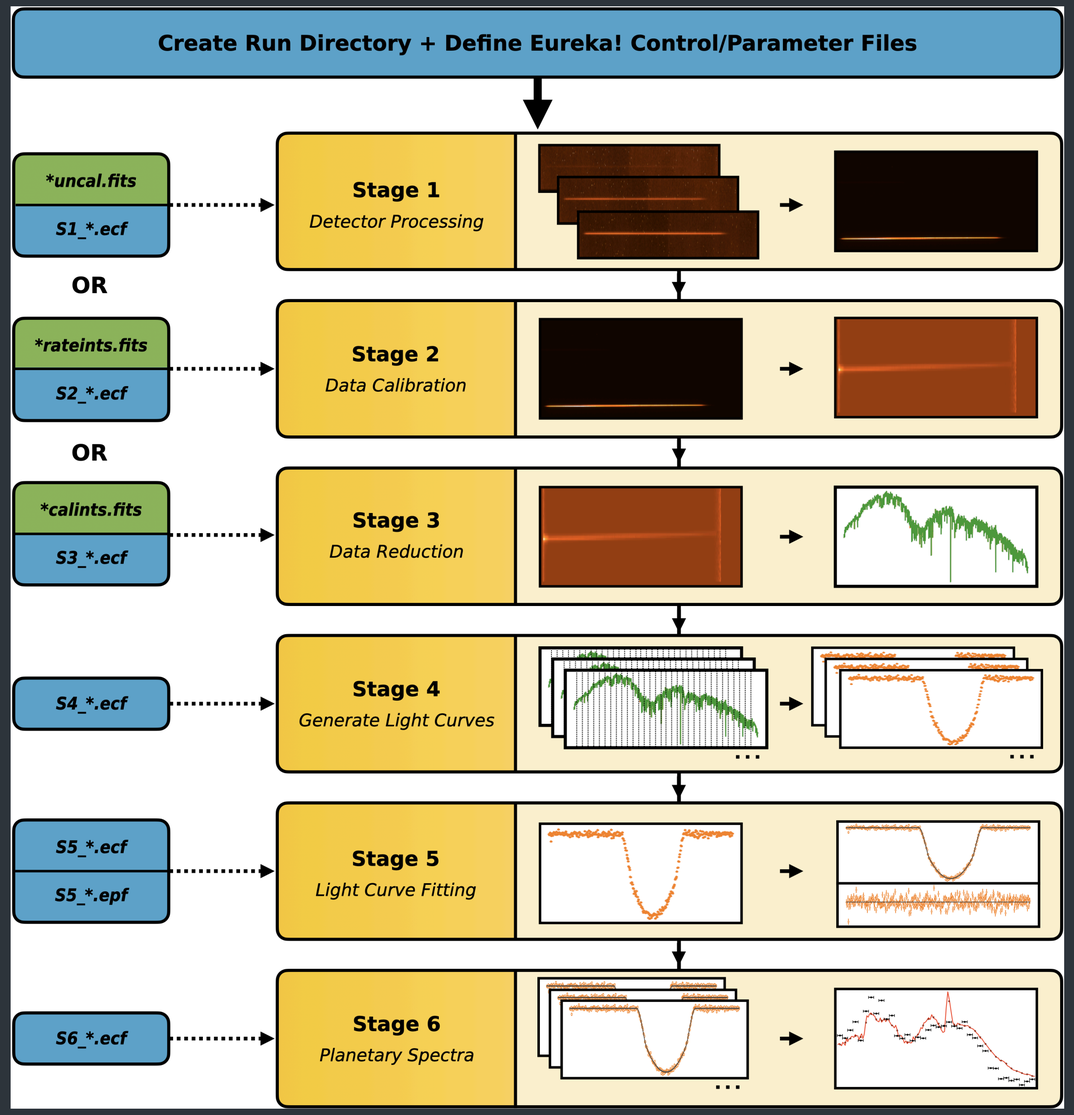
https://app.box.com/s/tj1jnivn9ekiyhecl5up7mkg8xrd1htl

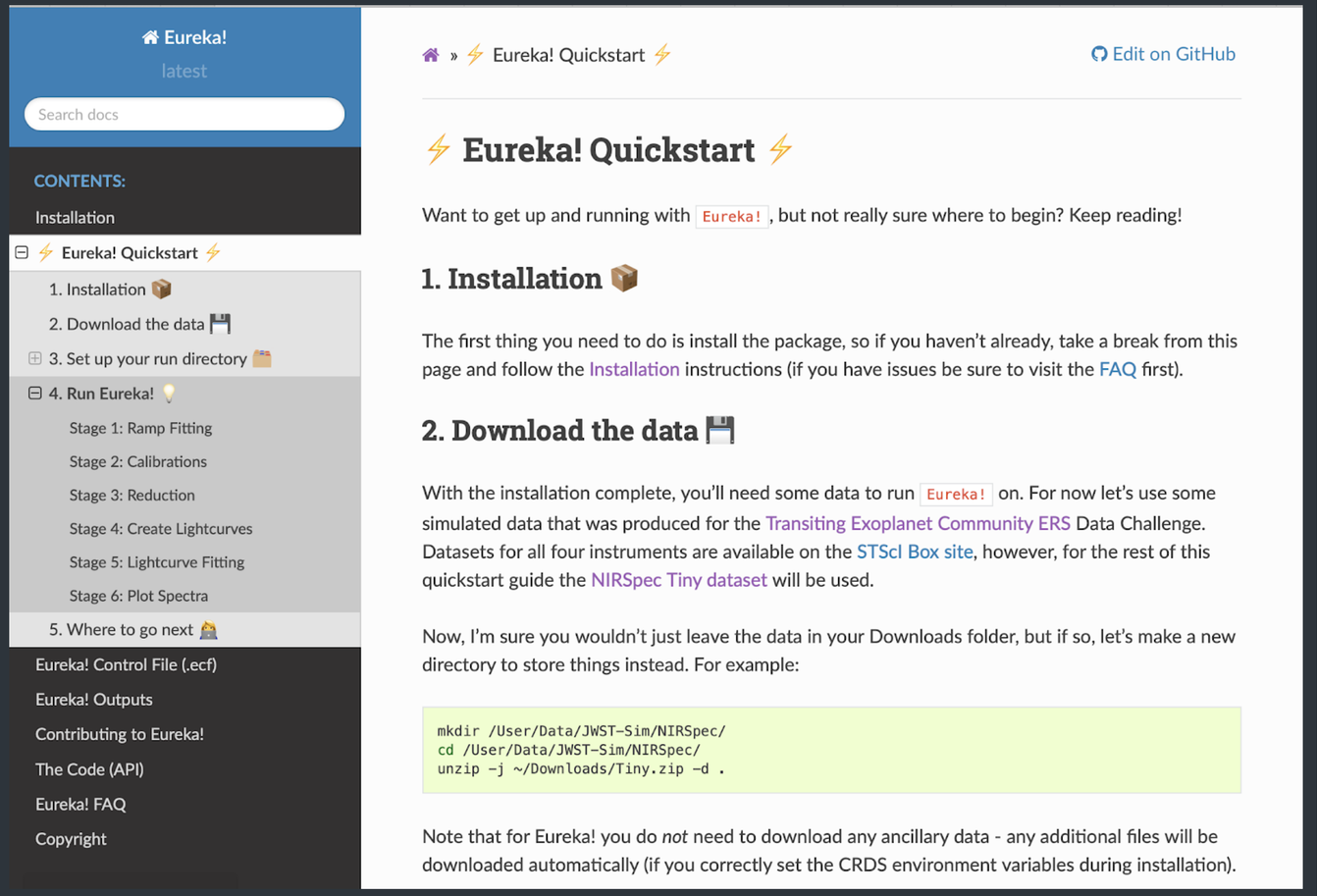
# Data Analysis Pipelines Are In Development

| | pixels to spectra: | spectra to features: |
|---|---|---|
| input | **Calibrated 2D pixel images.**  Calibrated 2D pixel images have basic instrumental signatures removed, ideally providing a good estimate of the rate at which photons hit each detector pixel. | **Extracted 1D stellar spectra.**  Extracted 1D stellar spectra record the rate of photons/second detected from the star-planet system at each wavelength throughout time. |
| output | **Extracted 1D stellar spectra.**  Extracted 1D stellar spectra record the rate of photons/second detected from the star-planet system at each wavelength throughout time. | **Fitted transit features.**  Fitted transit features represent measured transmission, emission, and/or phase curve spectra, along with uncertainties that account for instrumental and/or astrophysical systematics. |

**ERS Data Challenge with Simulated Data**
**21-23 March 2022 — Baltimore, Heidelberg, online**
**short talks + discussion + collaboration + coding**


# Pipeline Highlight - Eureka!




https://eurekadocs.readthedocs.io/en/latest/

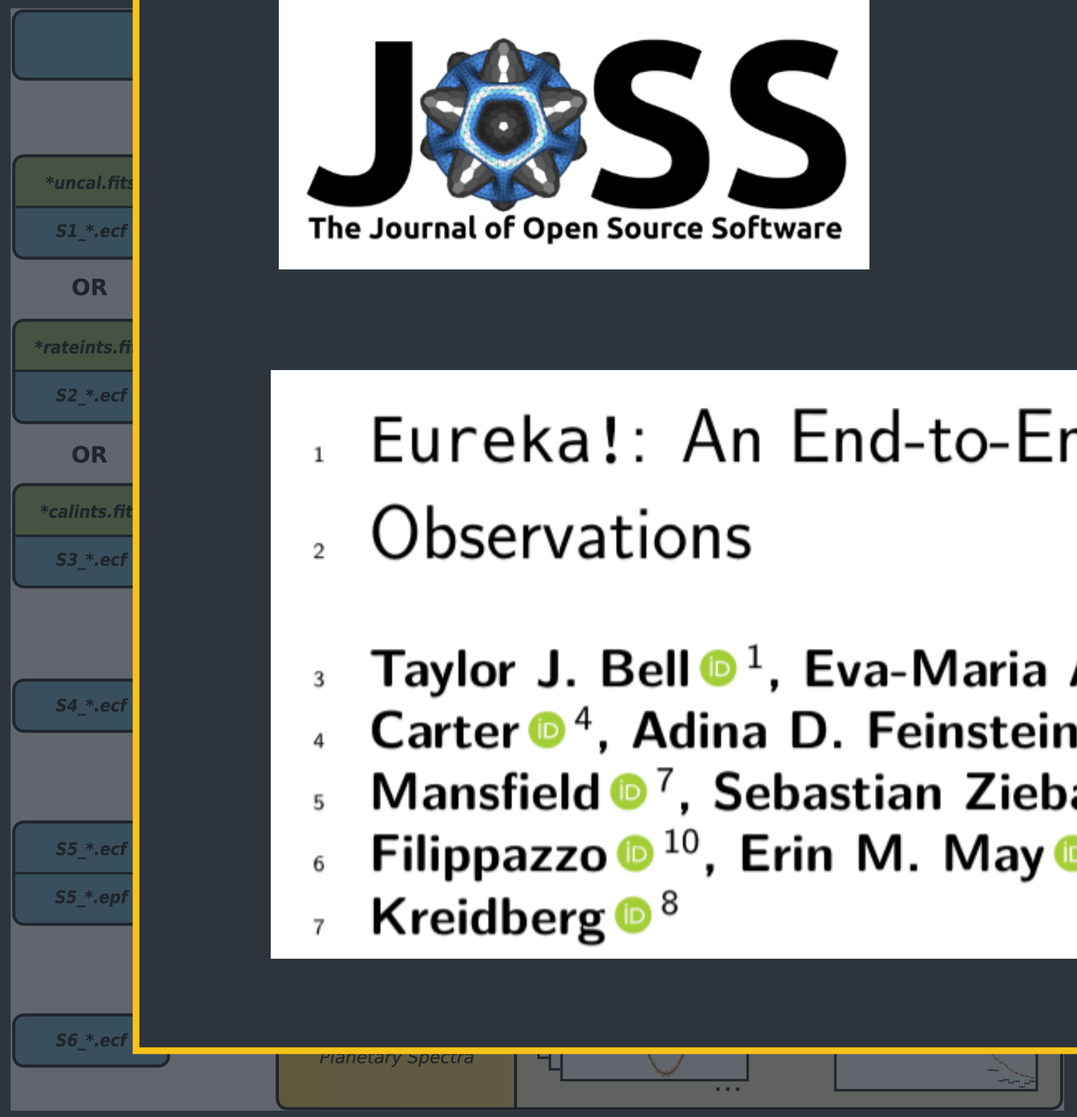
# Pipeline Highlight – Eureka!

JOSS
The Journal of Open Source Software

## Paper Submitted!

1 Eureka!: An End-to-End Pipeline for JWST Time-Series
2 Observations

3 Taylor J. Bell [1], Eva-Maria Ahrer [2], Jonathan Brande [3], Aarynn L.
4 Carter [4], Adina D. Feinstein [5], Giannina Guzman [6], Megan
5 Mansfield [7], Sebastian Zieba [8], Caroline Piaulet [9], Joseph
6 Filippazzo [10], Erin M. May [11], Kevin B. Stevenson [11], and Laura
7 Kreidberg [8]

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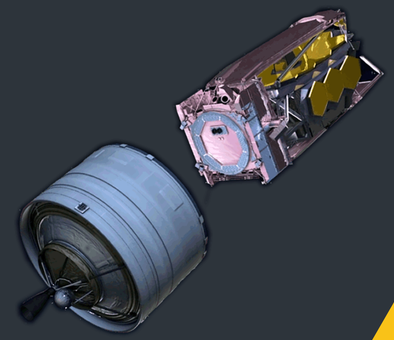

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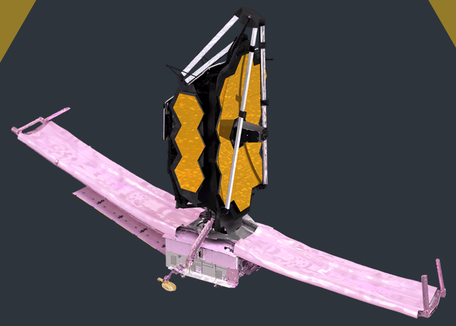

# The Goals of the Program

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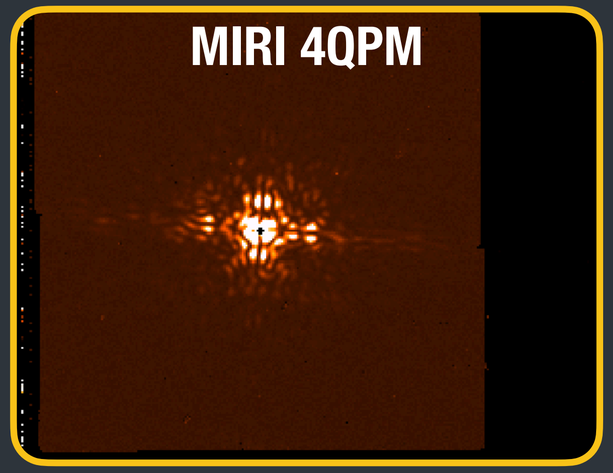
- Generate **representative datasets** for a range of modes across all 4 instruments aboard JWST, specific to the exoplanet and debris disk imaging community.



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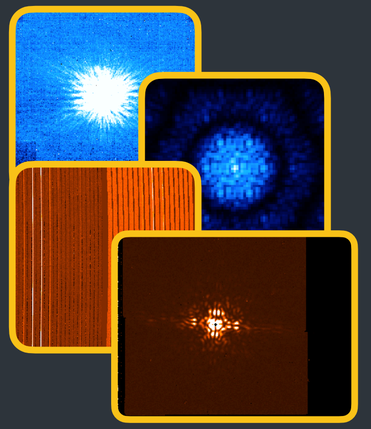
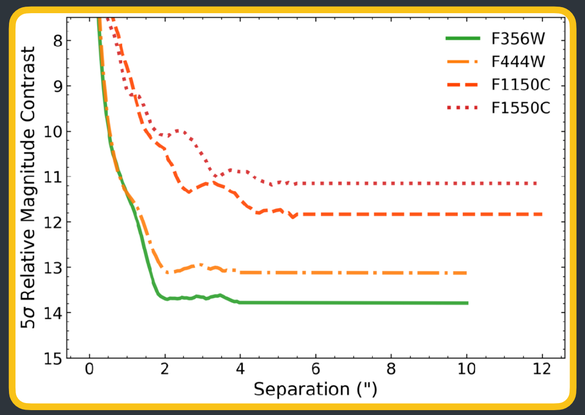
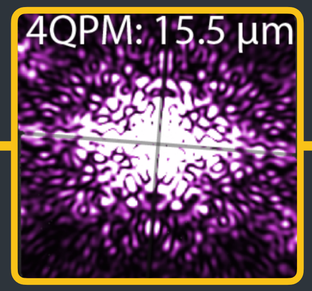
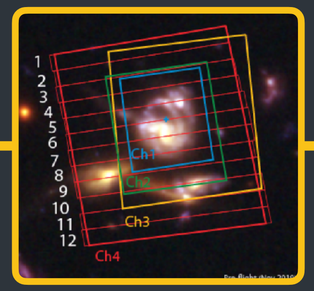


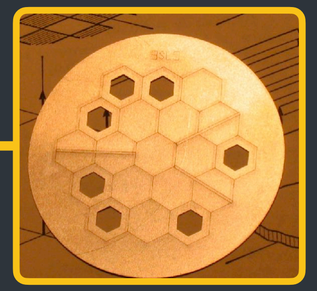
- Deliver a wide range of **science enabling products** to the community to aid with proposal planning, data reduction and interpretation.




python™

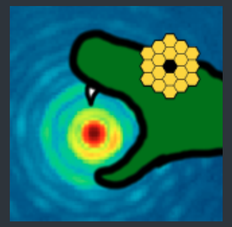



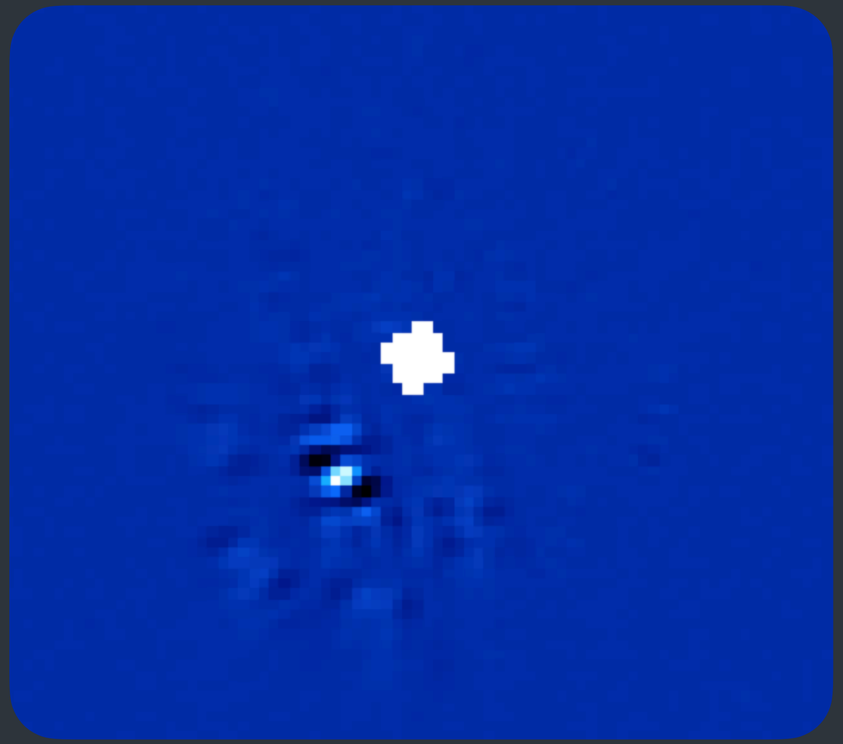



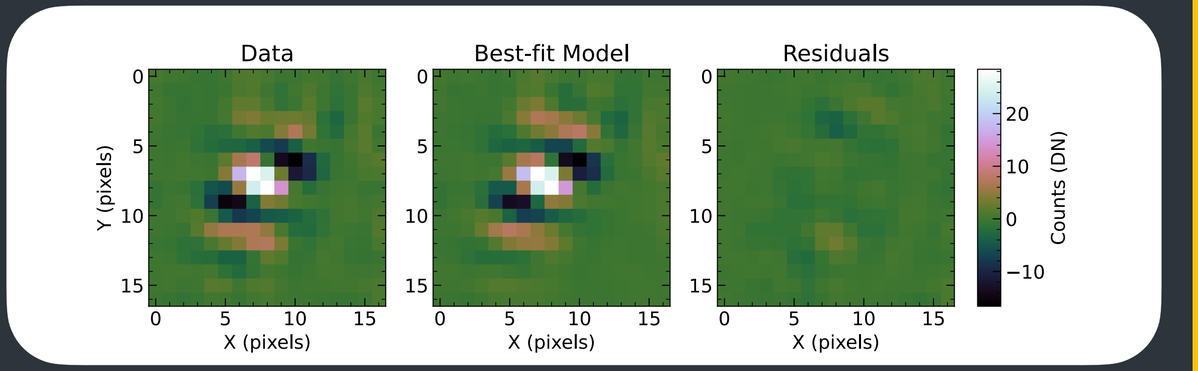



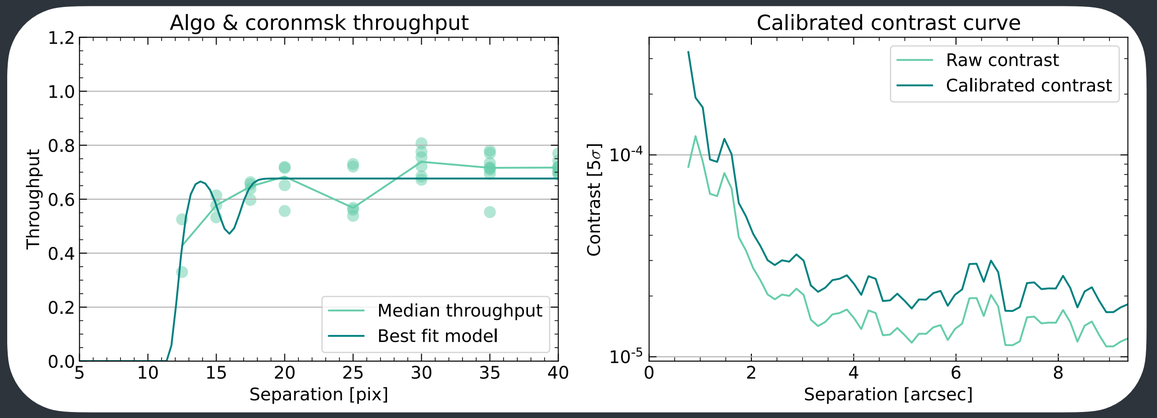
# The Goals of the Program

## NIRCam / MIRI Coronagraphy Pipeline:
## https://github.com/kammerje/spaceKLIP



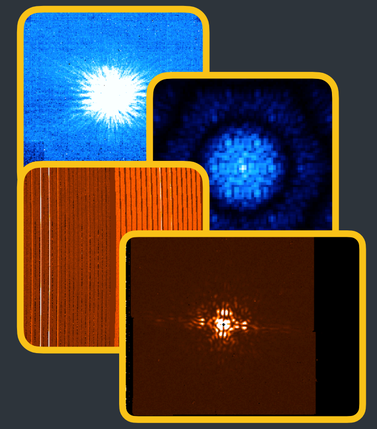




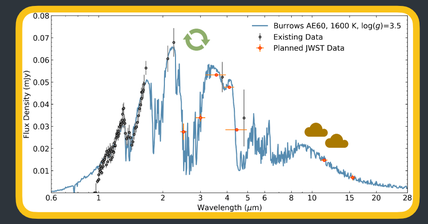
# The Goals of the Program

- Generate **representative datasets** for a range of modes across all 4 instruments aboard JWST, specific to the exoplanet and debris disk imaging community.



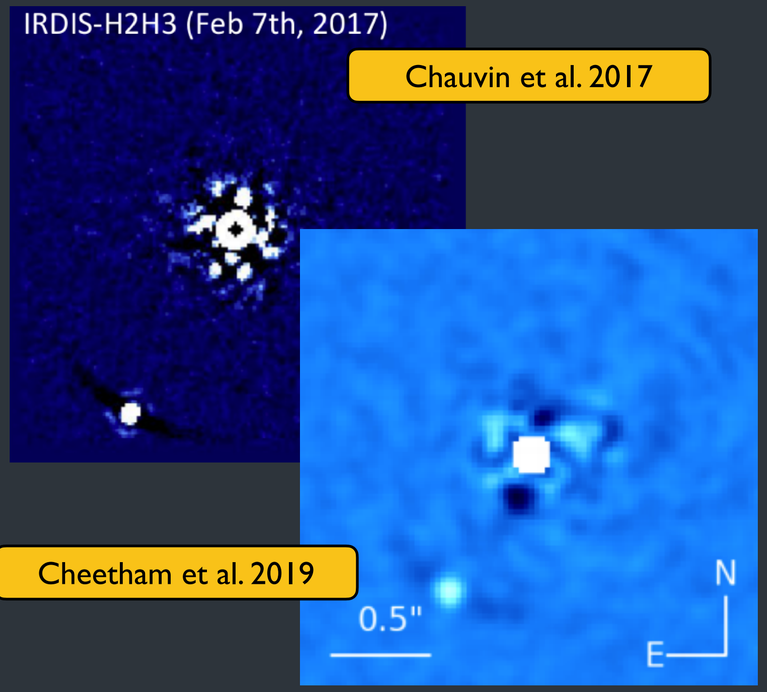
- Deliver a wide range of **science enabling products** to the community to aid with proposal planning, data reduction and interpretation.

- **Characterise directly imaged exoplanets and disks in the near- to mid-infrared for the first time.**



## HIP 65426 b

~7-9 $M_{Jup}$, 1300-1600 K



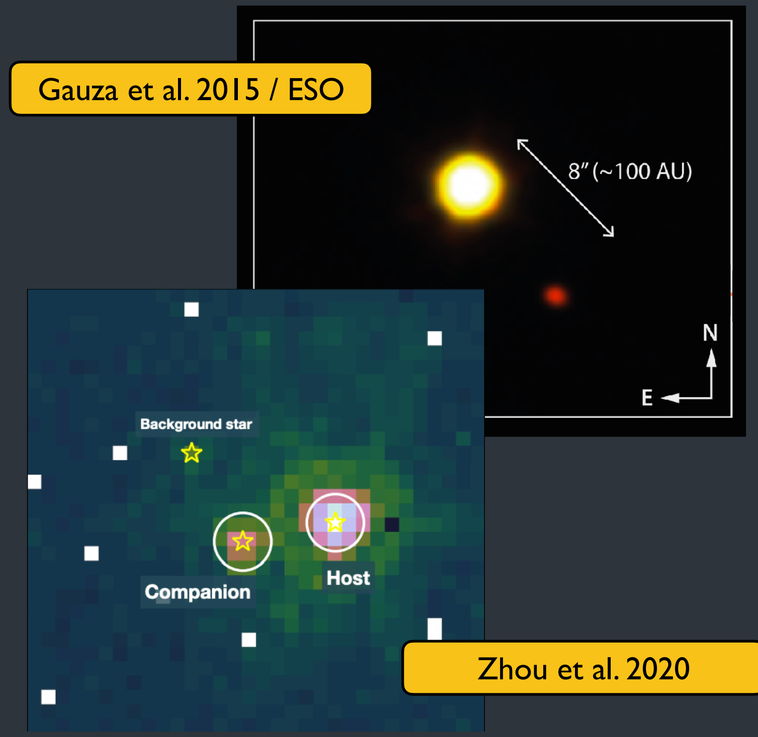

Chauvin et al. 2017

Cheetham et al. 2019

Coronagraphic imaging from 3-15 microns

## VHS 1256 b

~14-24 $M_{Jup}$, 1000-1200 K



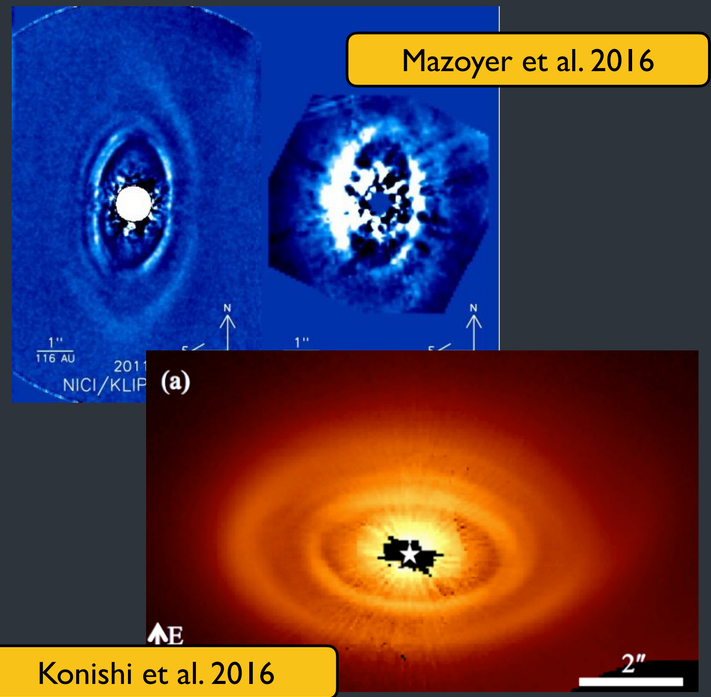

Gauza et al. 2015 / ESO

Zhou et al. 2020

Spectroscopy from 0.6-28 microns at R>1000

## HD 141569 A

Triple ring disk system

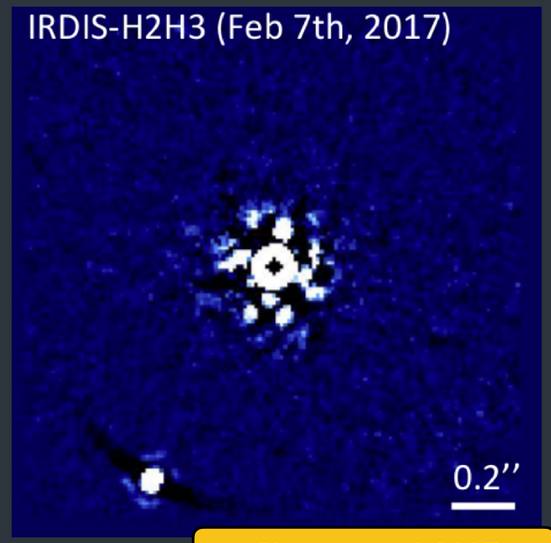



Mazoyer et al. 2016

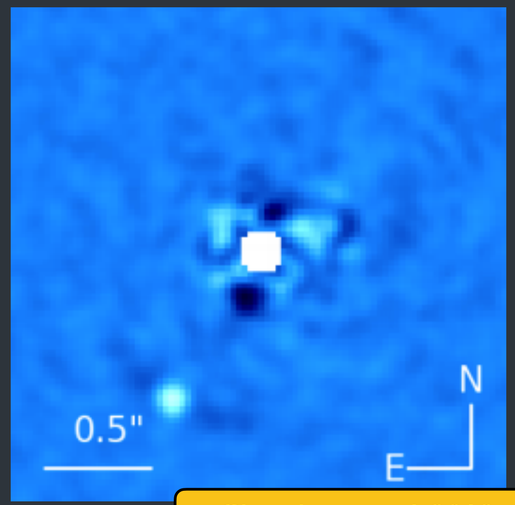
Konishi et al. 2016

Coronagraphic imaging from 3-15 microns

# HIP 65426 b

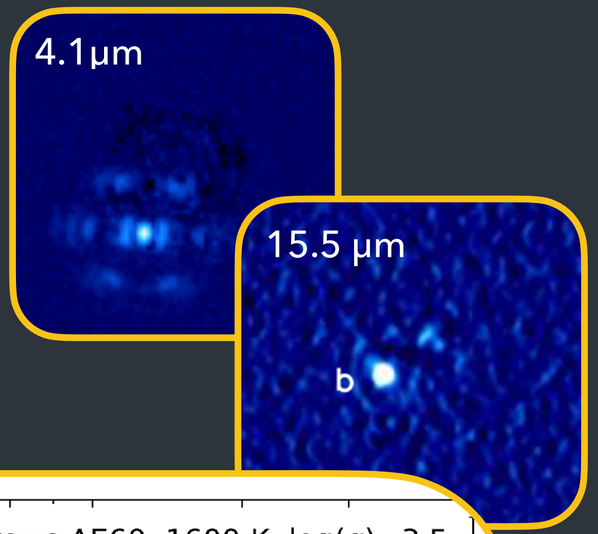


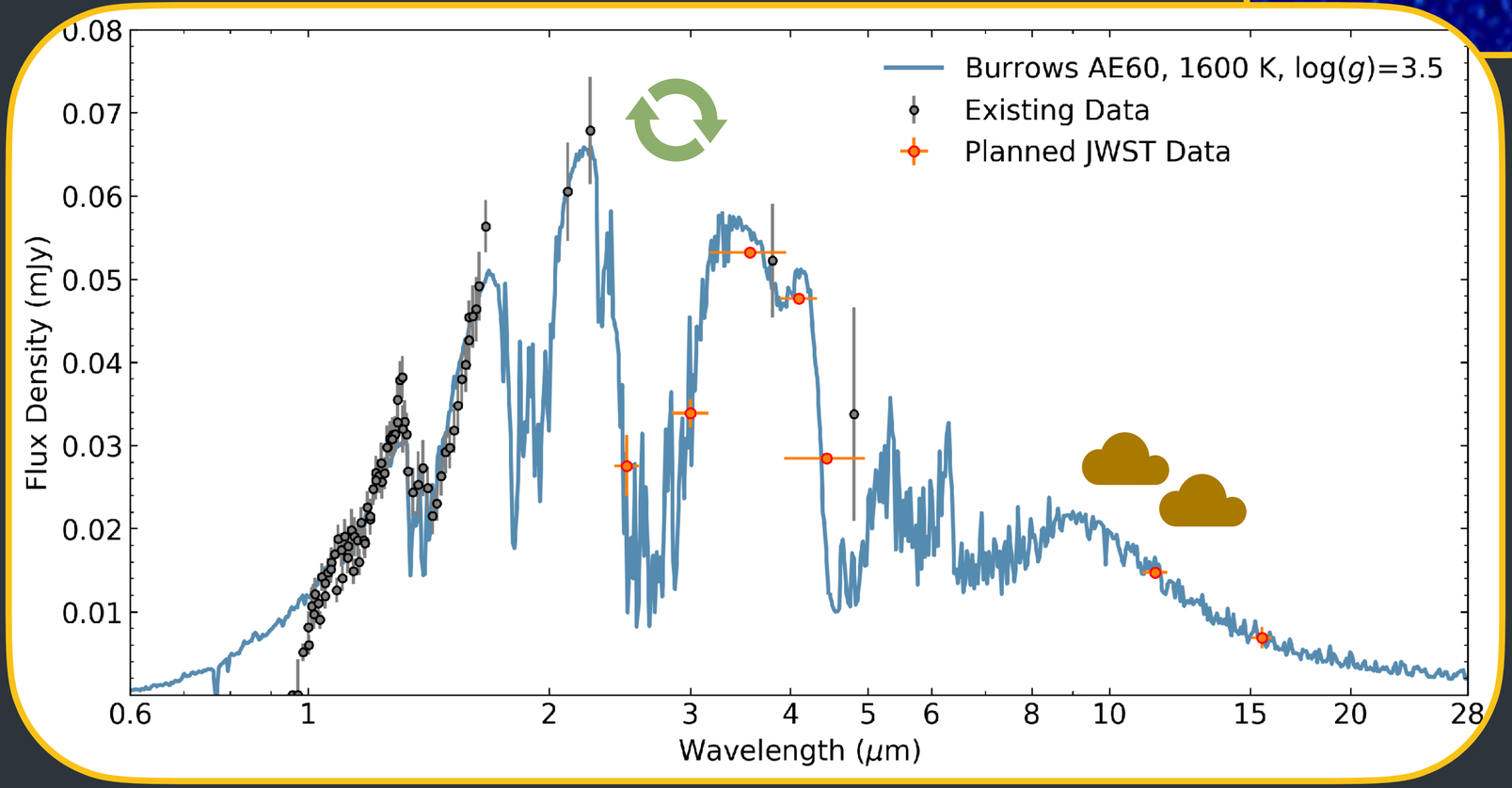

Chauvin et al. 2017



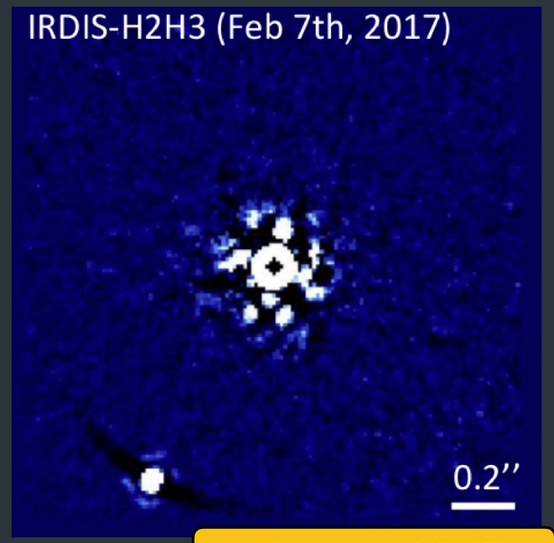

Cheetham et al. 2019

- Close separation of ~0.83 arcsec necessitates NIRCam and MIRI coronagraphy.
- Utilise a range of filters to better characterise the atmosphere.

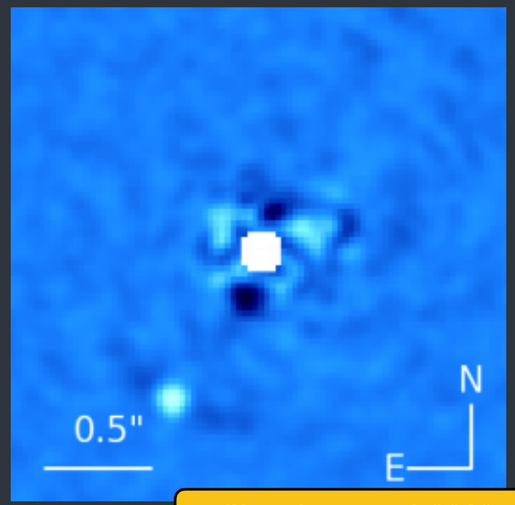


# HIP 65426 b

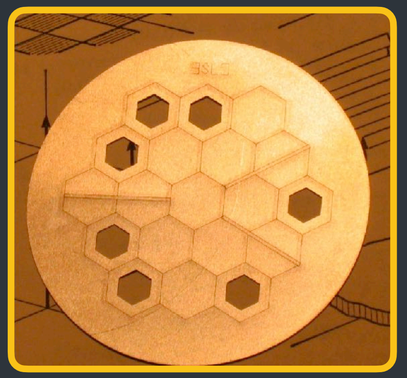



Chauvin et al. 2017

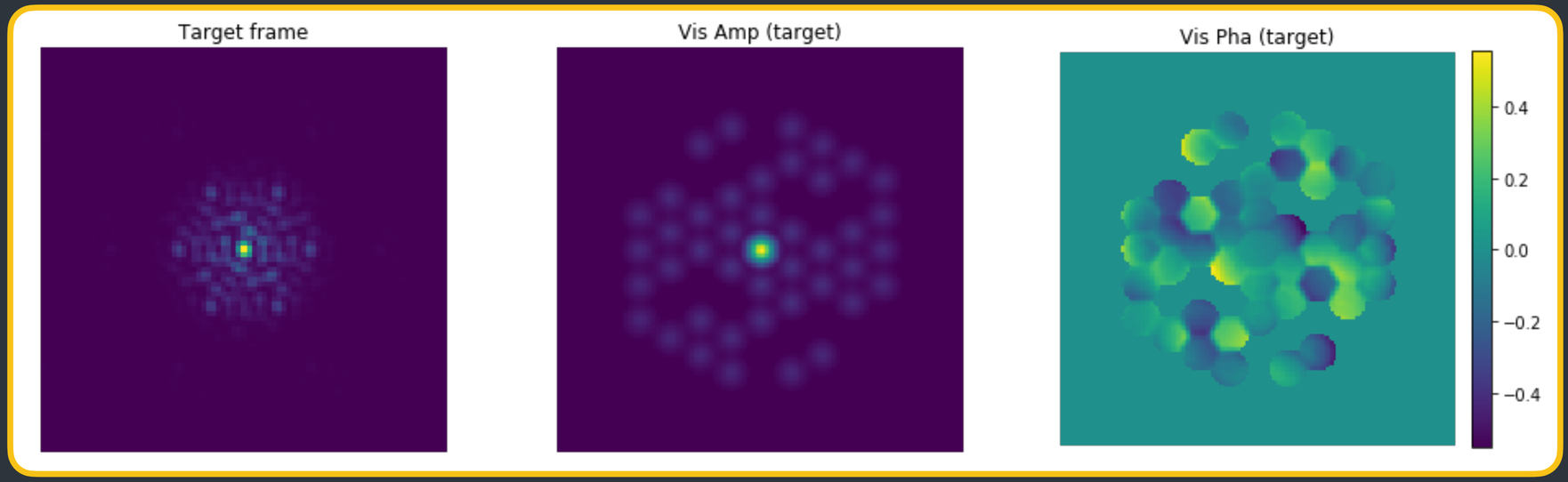



Cheetham et al. 2019

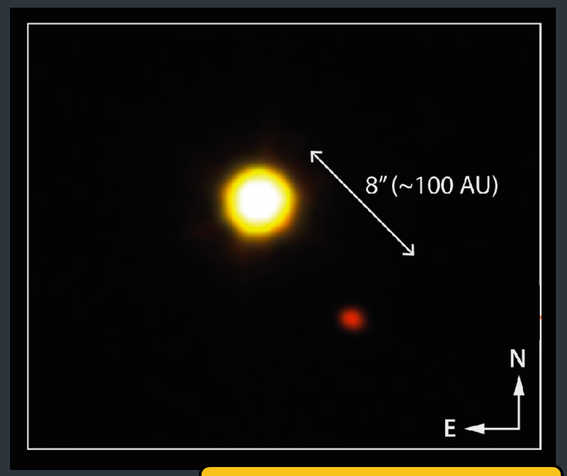
- Also explore innermost system architecture using NIRISS aperture masking interferometry (0.04-0.7 arcsec).



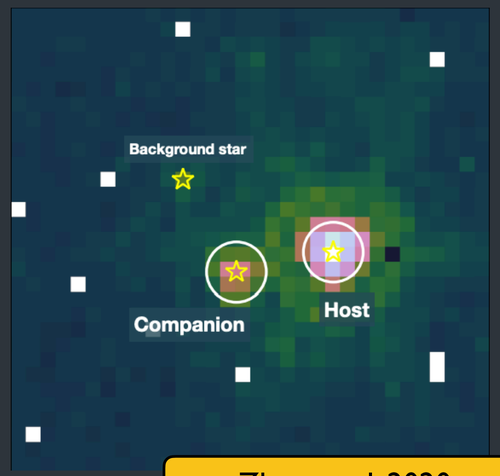
$$R = 1.22\,\frac{\lambda}{D} \quad \rightarrow \quad R = 0.5\,\frac{\lambda}{D}$$



# VHS 1256 b

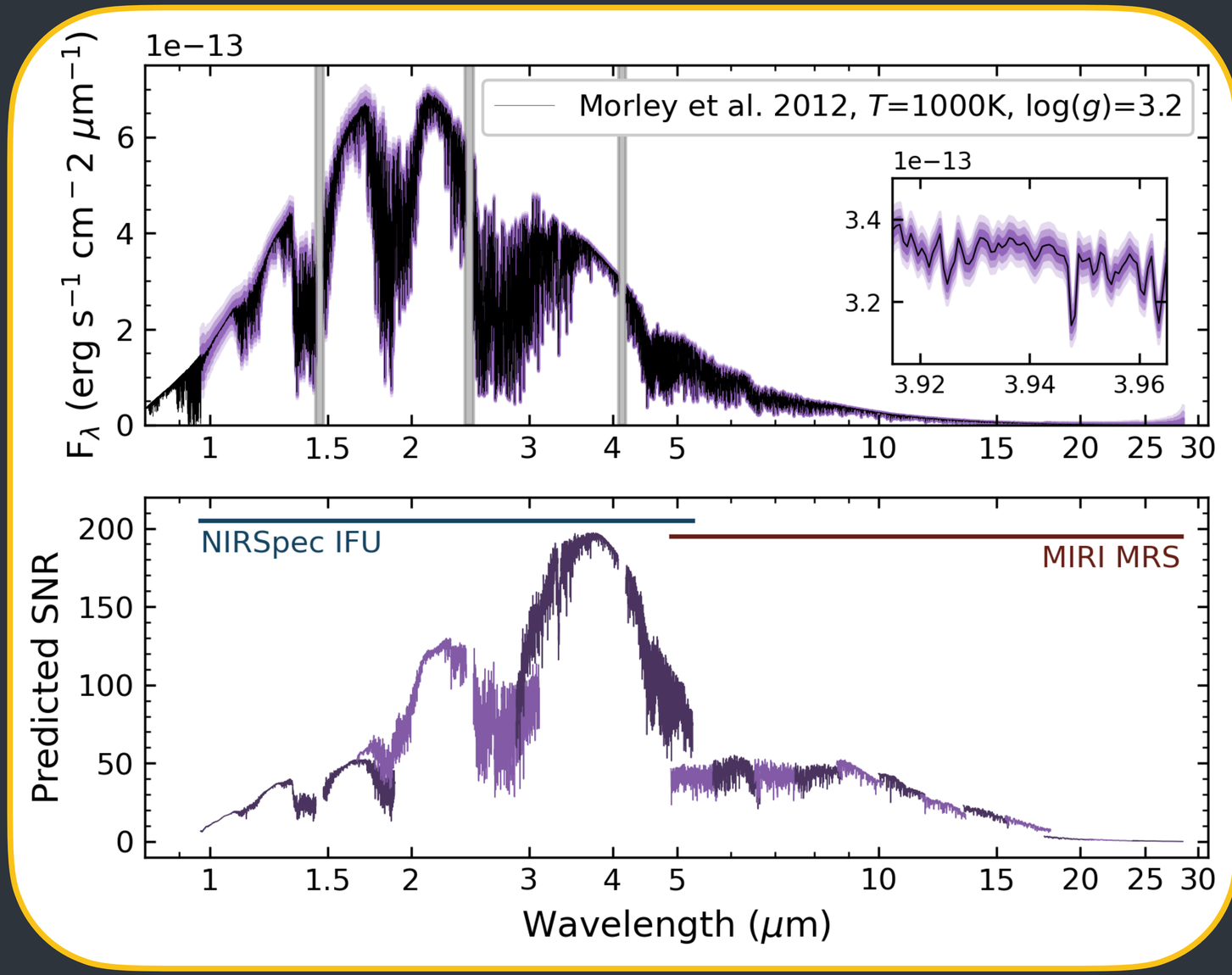



Gauza et al. 2015 / ESO

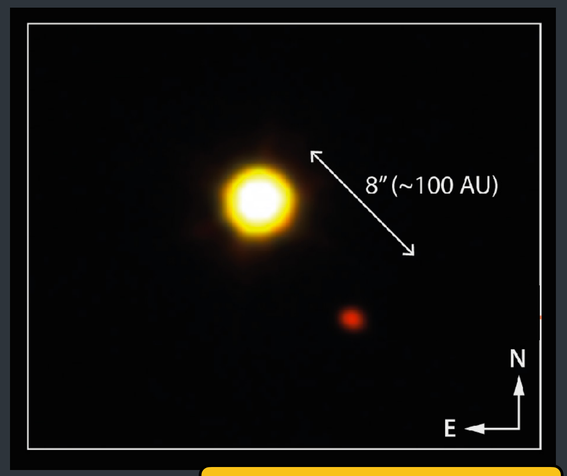



Zhou et al. 2020

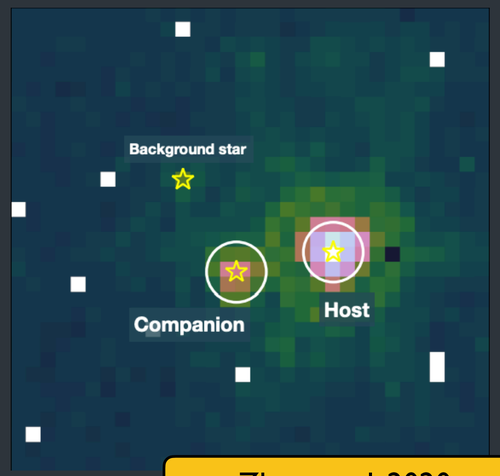
- Large separation enables NIRSpec and MIRI IFU Spectroscopy from 0.7-28 microns.



# VHS 1256 b

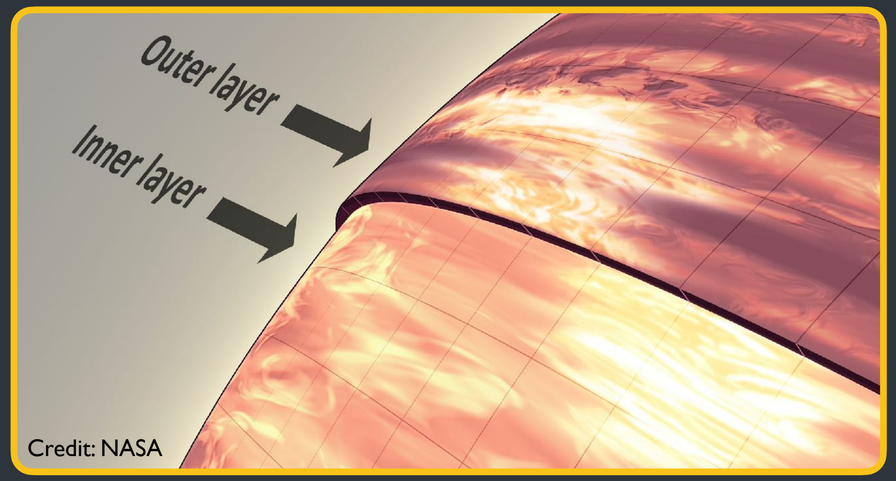


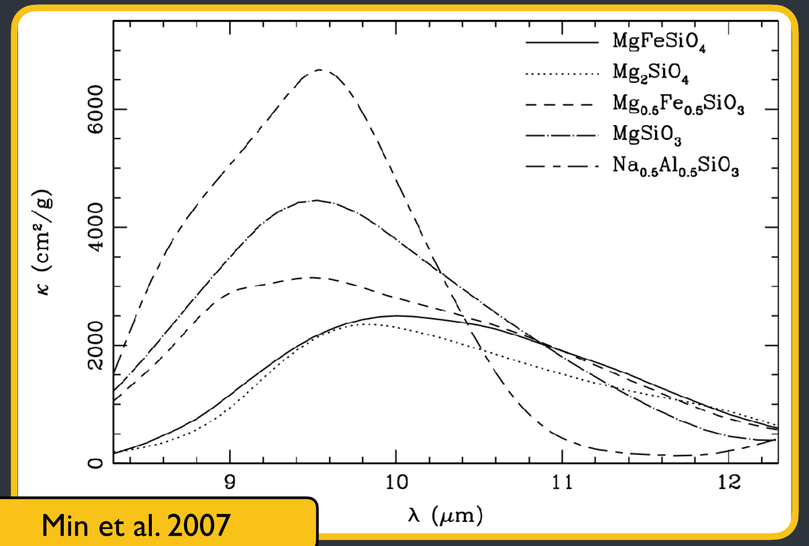

Gauza et al. 2015 / ESO




Zhou et al. 2020

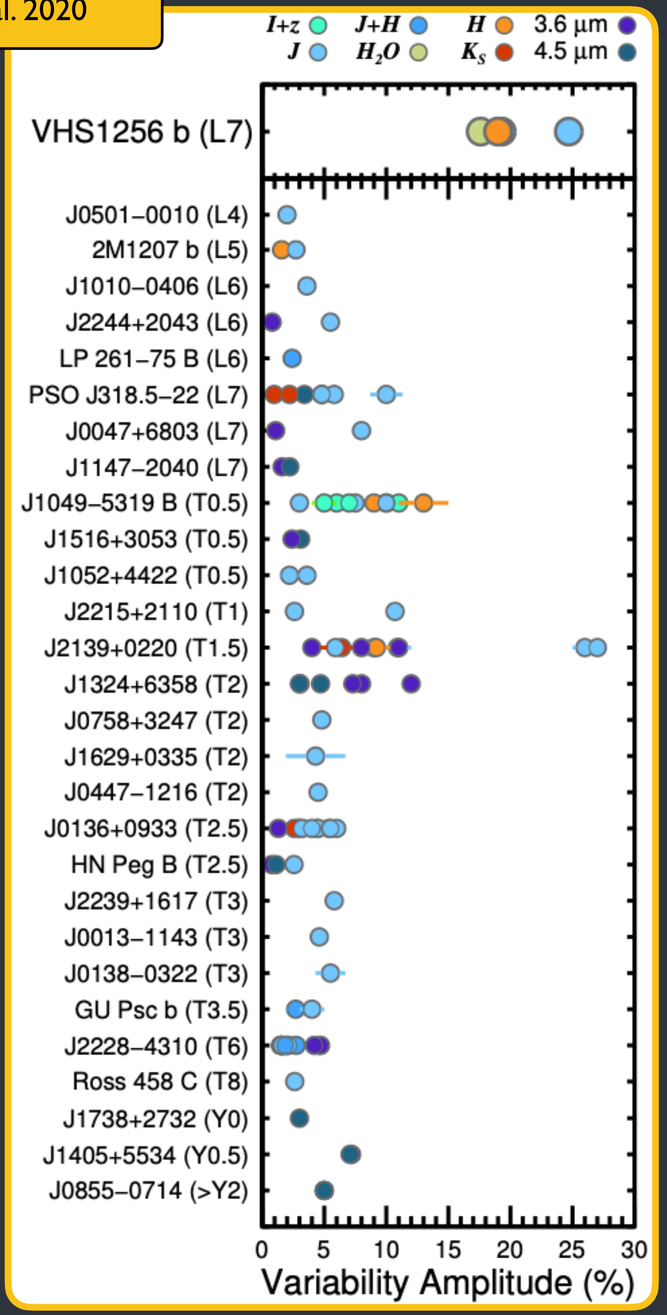
- Large variability amplitude indicative of variable cloud coverage.



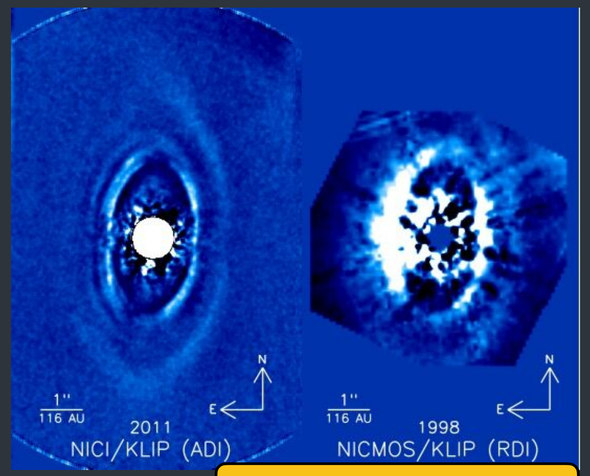

Min et al. 2007

Bowler et al. 2020
Zhou et al. 2020

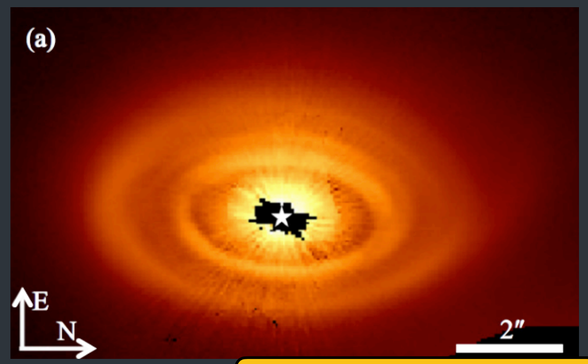


# HD 141569 A

- NIRCam and MIRI coronagraphy at 3.0, 3.6, 10.65, 11.40, and 15.50 microns.

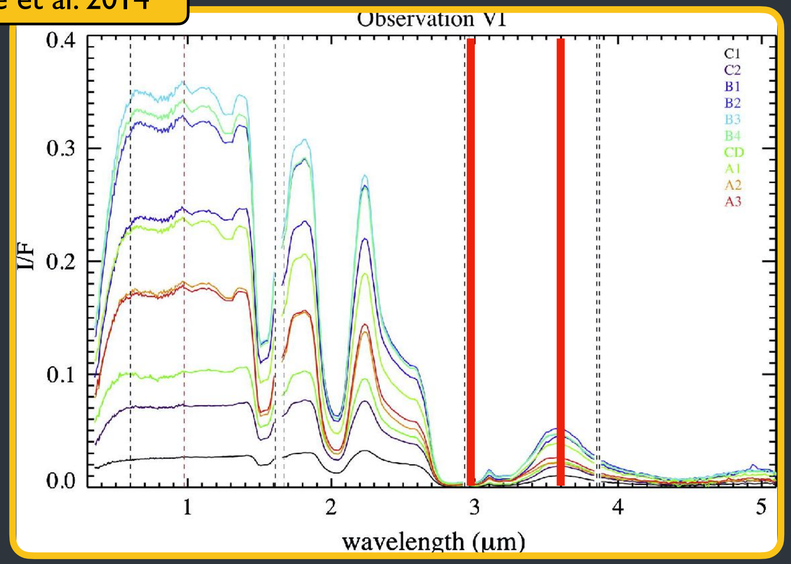


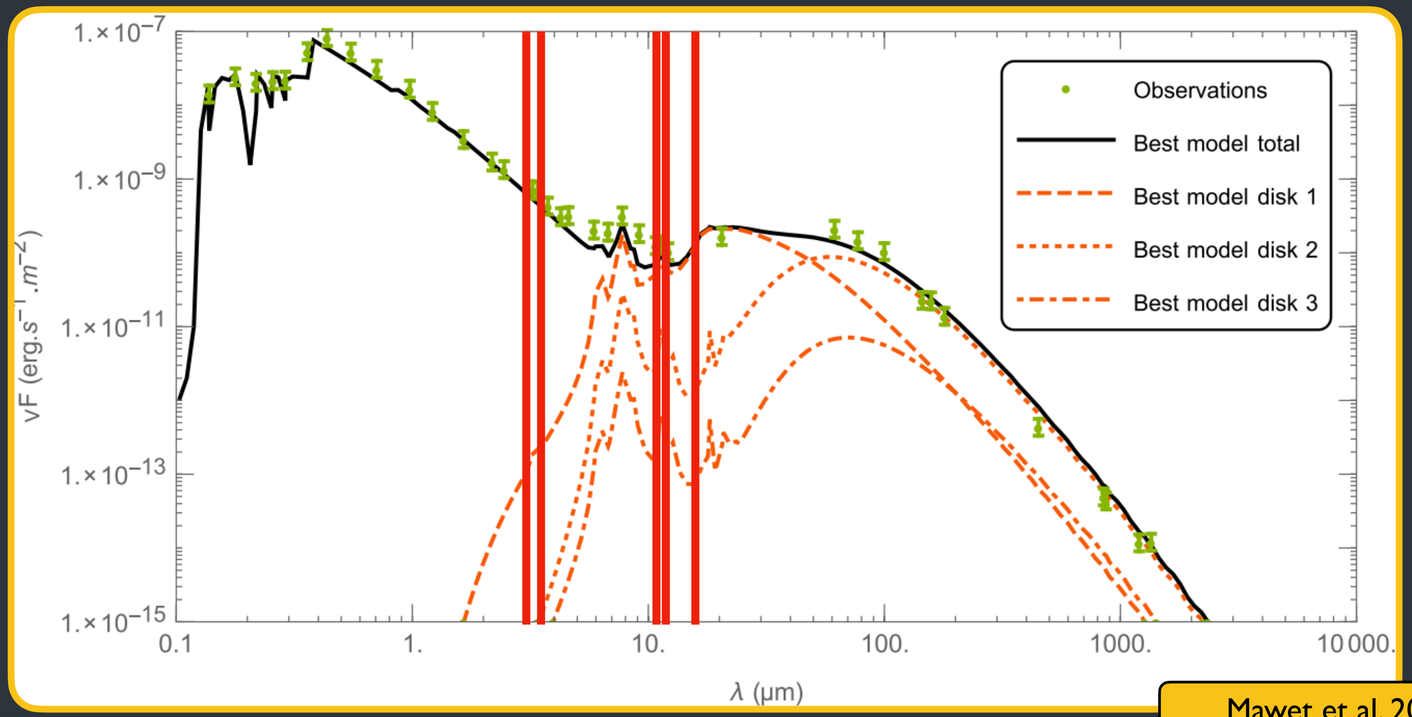

Mazoyer et al. 2016




Konishi et al. 2016

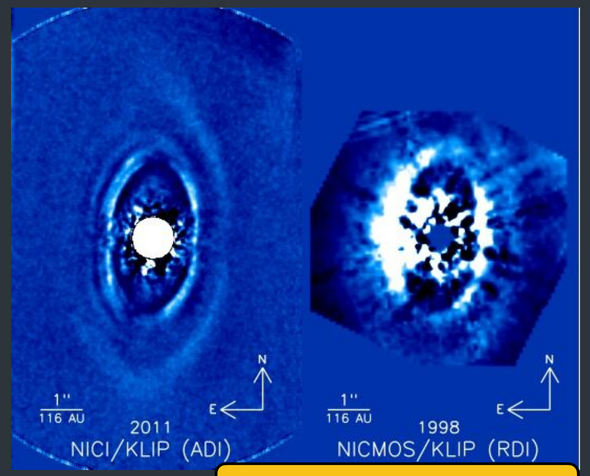
Filacchione et al. 2014



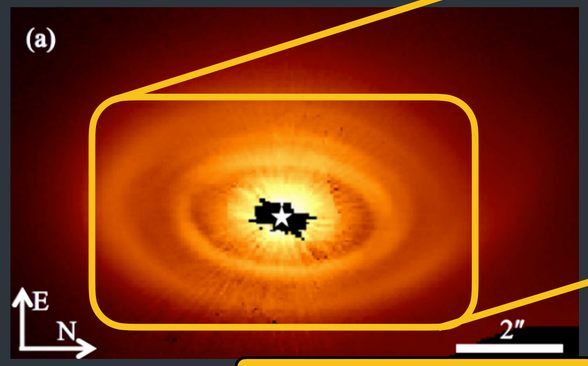




Mawet et al. 2017

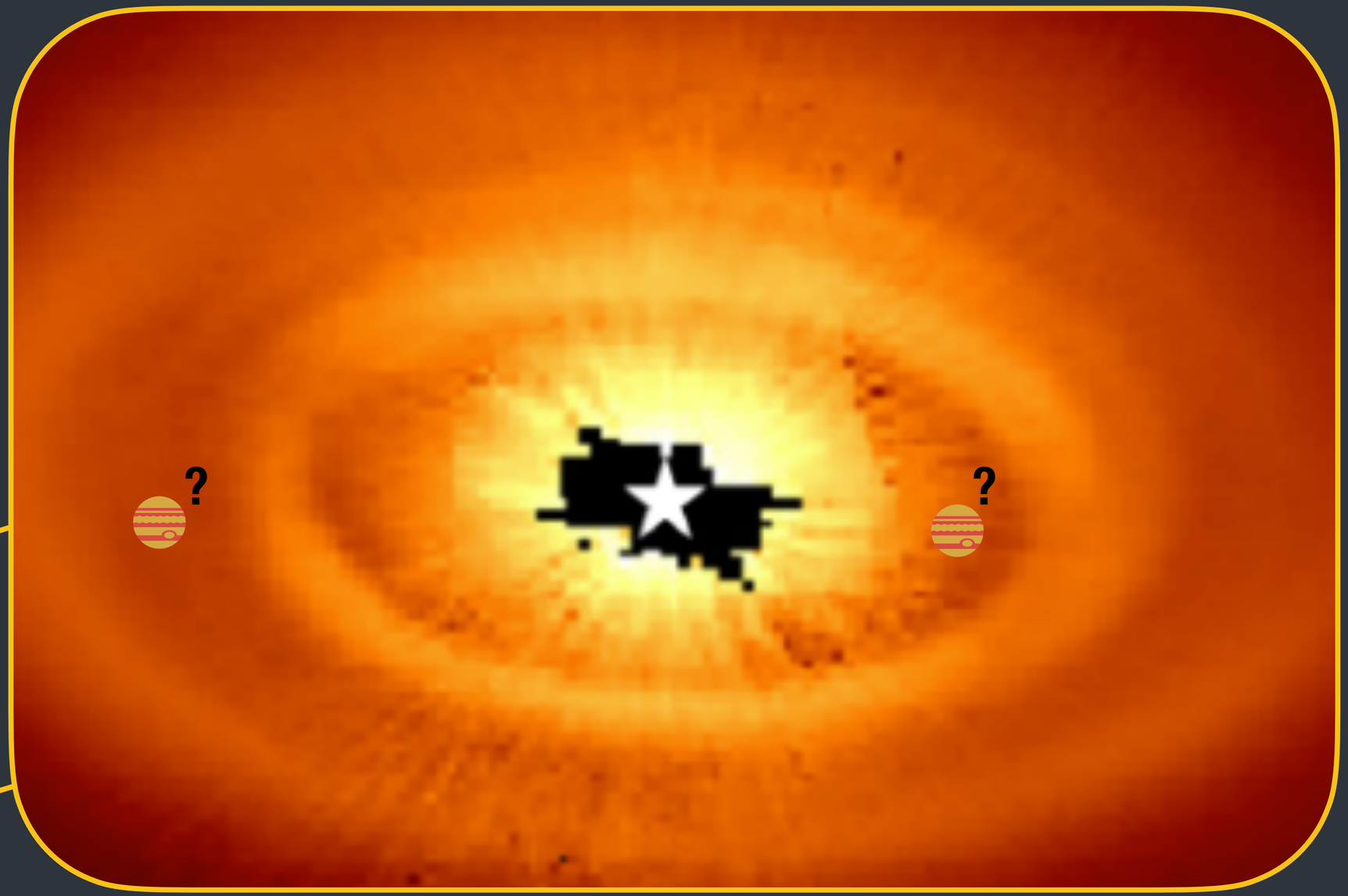
# HD 141569 A




Mazoyer et al. 2016




Konishi et al. 2016

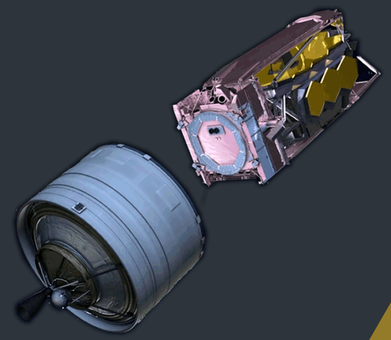


# Paper Out Now!

# https://arxiv.org/abs/2205.12972

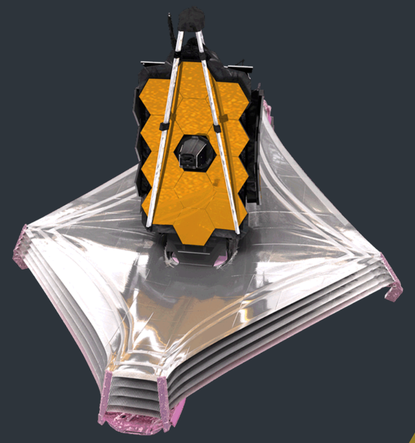

+Others!

Introduction to JWST ERS



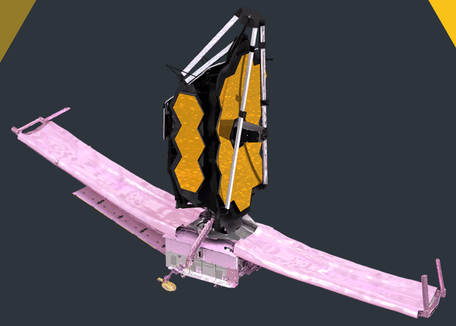
Transiting Exoplanet ERS Program

Direct Imaging Exoplanet ERS Program



What's In A Name?

Conclusions



**“I will say there is no clear answer that will distance Webb from claims of homophobia. I certainly wouldn’t argue he was a crusader against LGBTQ, but, you can’t argue that he did not facilitate that process as well.”**

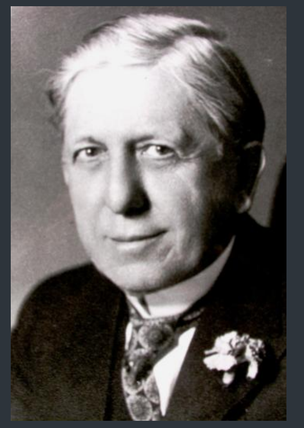
**- Brian C. Odom, Acting NASA Chief Historian, March 21 2021**

*Page 28, Supplementary Information, https://www.nature.com/articles/d41586-022-00845-6*

# June 22 1950

**President Truman and then Undersecretary of State James Webb meet and discuss how the Hoey Committee and the White House might "*work together on the homosexual investigation*".**

*President Harry Truman (Left), James Webb (Right)*



*Senator Clyde Hoey*

## Meeting is arranged for June 28

*Congressional Record: Proceedings and Debates of the United States Congress, Volume 96, Part 6, Page 8209*
*David K. Johnson, The Lavender Scare: The Cold War Persecution of Gays and Lesbians in the Federal Government*

# June 23 1950

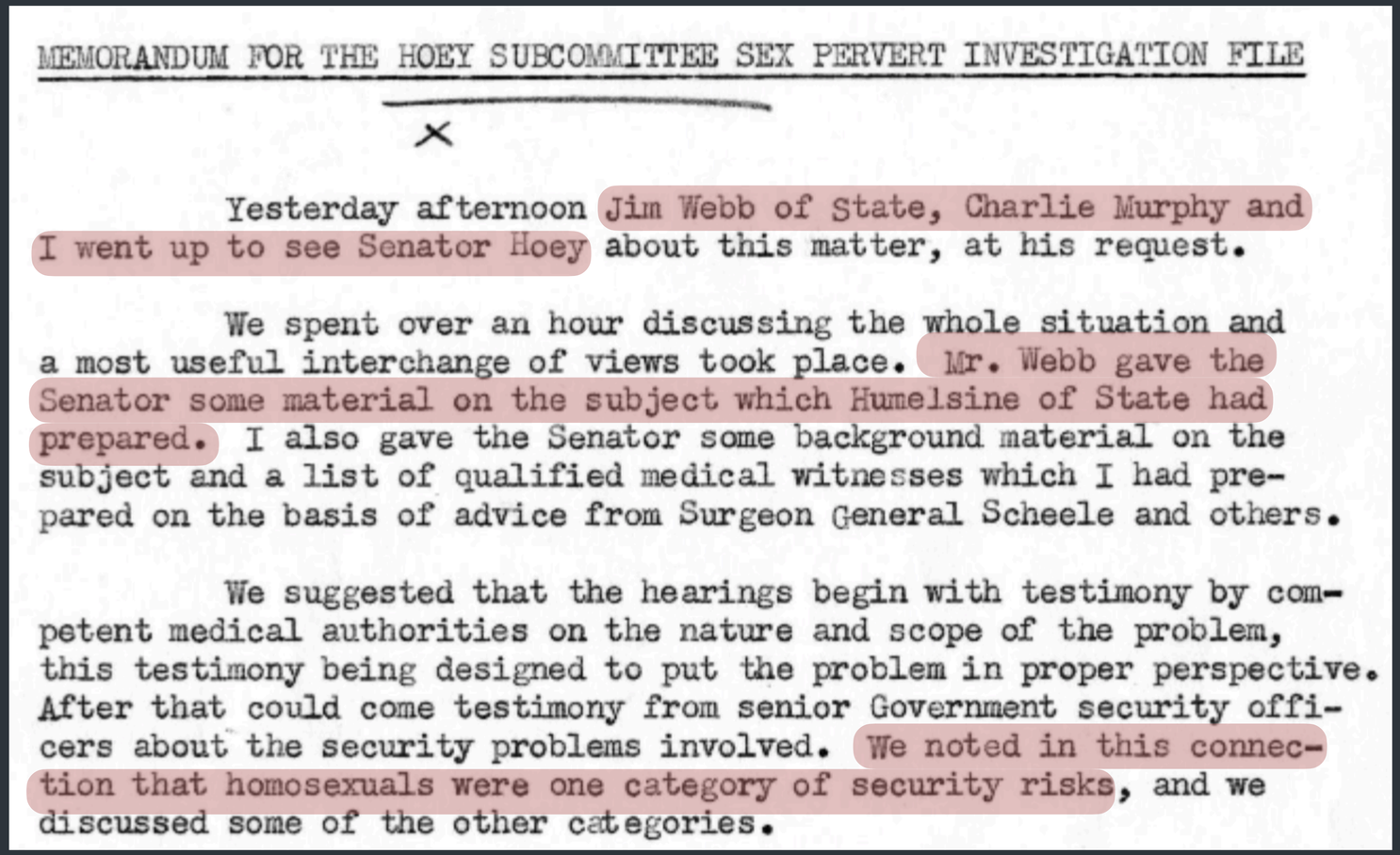
## Deputy Undersecretary Carlisle Humelsine shares a background paper on "*Problem of Homosexuals and Sex Perverts in the Department of State*" with James Webb

Our investigations and studies of the subject revealed that homosexuals are, generally speaking, undesirable as employees for a number of reasons: (1) They create a morale problem, i.e., most men who are considered by the majority of us to be normal desire not to work or associate with homosexuals; (2) They are emotionally unstable, i.e., many of them have told our investigators of the inexorable pain and humiliation they would suffer if exposed to family and friends, and some have even threatened suicide; (3) Usually they live in a world all to themselves associating and consorting with other homosexuals; (4) They indulge in acts of perversion which are legion and which are abhorent and repugnant to the folkways and mores of our American society; (5) They are immoral in their sexual behavior seeking sexual gratification from one person one night and from another person the next in a paltry and endless gesture at a happiness they never realize.


*Carlisle Humelsine, outlet.historicimages.com*

https://catalog.archives.gov/id/54538192
https://catalog.archives.gov/id/2666952
https://lgbtqarchives.tumblr.com/post/152657311157/cover-label-of-information-on-homosexuals-folder

# June 28 1950



MEMORANDUM FOR THE HOEY SUBCOMMITTEE SEX PERVERT INVESTIGATION FILE

Yesterday afternoon Jim Webb of State, Charlie Murphy and I went up to see Senator Hoey about this matter, at his request.

We spent over an hour discussing the whole situation and a most useful interchange of views took place. Mr. Webb gave the Senator some material on the subject which Humelsine of State had prepared. I also gave the Senator some background material on the subject and a list of qualified medical witnesses which I had prepared on the basis of advice from Surgeon General Scheele and others.

We suggested that the hearings begin with testimony by competent medical authorities on the nature and scope of the problem, this testimony being designed to put the problem in proper perspective. After that could come testimony from senior Government security officers about the security problems involved. We noted in this connection that homosexuals were one category of security risks, and we discussed some of the other categories.

**James Webb meets with Senator Hoey, chooses to distribute the homophobic paper, and discusses how testimony should be provided in the investigation hearings.**

https://catalog.archives.gov/id/54538202

# December 15 1950

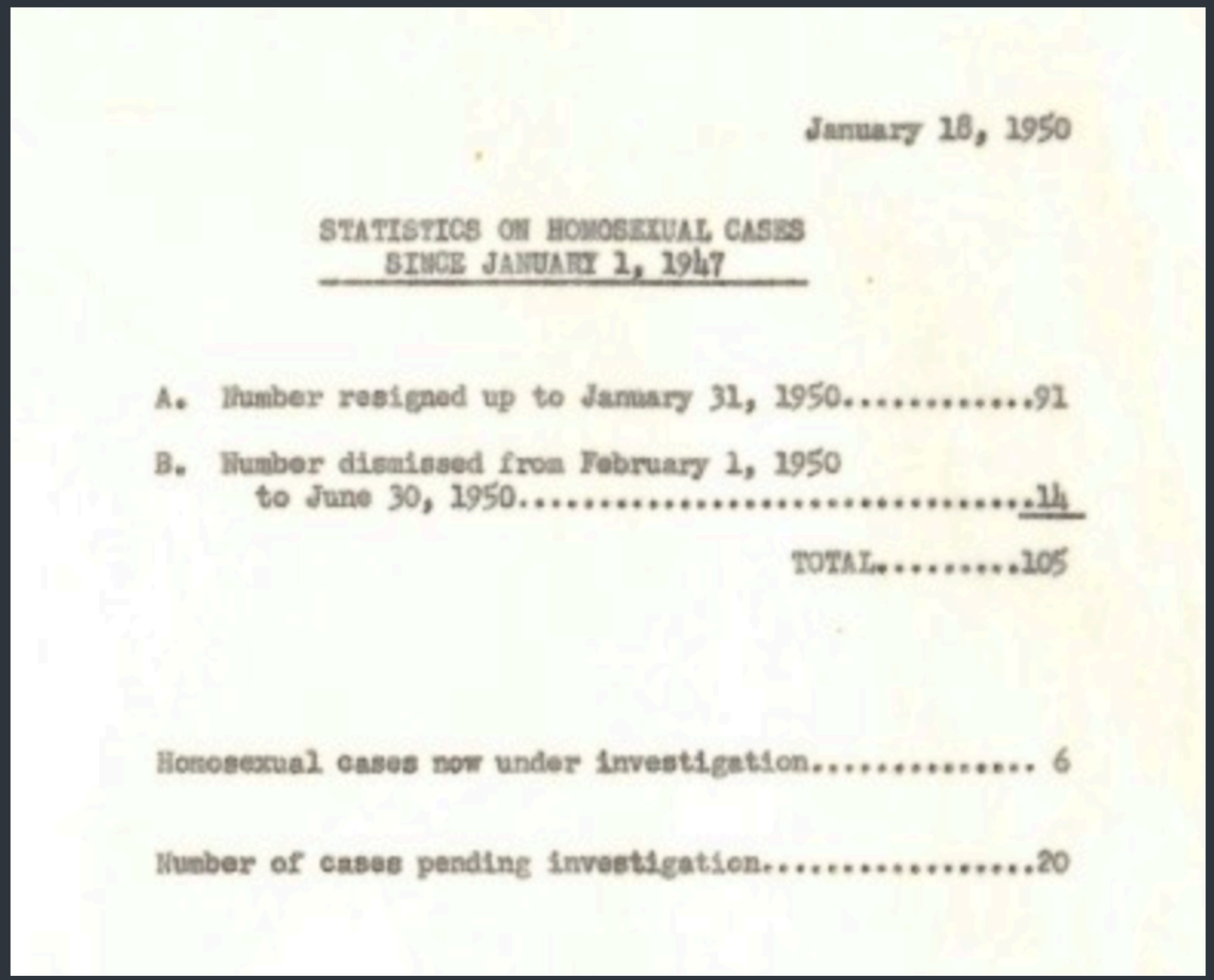
## CONCLUSION

There is no place in the United States Government for persons who violate the laws or the accepted standards of morality, or who otherwise bring disrepute to the Federal service by infamous or scandalous personal conduct. Such persons are not suitable for Government positions and in the case of doubt the American people are entitled to have errors of judgment on the part of their officials, if there must be errors, resolved on the side of caution. It is the opinion of this subcommittee that those who engage in acts of homosexuality and other perverted sex activities are unsuitable for employment in the Federal Government. This conclusion is based upon the fact that persons who indulge in such degraded activity are committing not only illegal and immoral acts, but they also constitute security risks in positions of public trust.

**5000 to tens of thousands lost their jobs**

https://catalog.archives.gov/id/54538202
https://www.archives.gov/publications/prologue/2016/summer/lavender.html

# State Department Employees Removed



January 18, 1950

STATISTICS ON HOMOSEXUAL CASES
SINCE JANUARY 1, 1947

A. Number resigned up to January 31, 1950.....91

B. Number dismissed from February 1, 1950
to June 30, 1950.....14

TOTAL.....105

Homosexual cases now under investigation..... 6

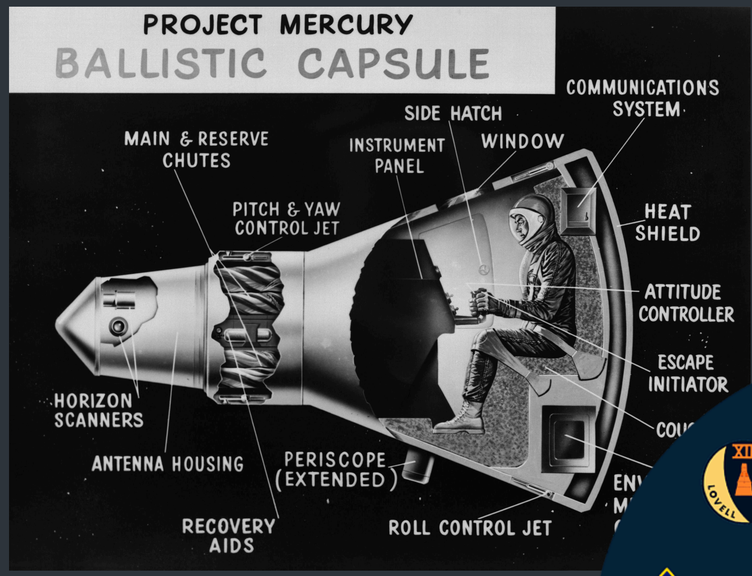
Number of cases pending investigation.....20

## Clifford L. Norton, NASA Employee Fired in 1963

NASA concluded that appellant did in fact make a homosexual advance on October 22, and that this act amounted to "immoral, indecent, and disgraceful conduct." It also determined that on the basis of his own admissions to Fugler, even as subsequently clarified, appellant possesses "traits of character and personality which render [him] * * unsuitable for further Government employment."

https://law.justia.com/cases/federal/appellate-courts/F2/417/1161/190082/
https://lgbtqarchives.tumblr.com/post/156600012522/statistics-on-homosexual-cases-since-january-1

*James Webb*






*Images Credits: NASA*

# Some Concluding Thoughts

- We cannot know for a fact what James Webb's inner thoughts and intentions were. But…

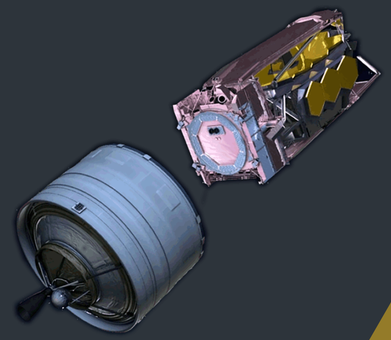
- "If you are neutral in situations of injustice, you have chosen the side of the oppressor" - Desmond Tutu

- An extraordinary observatory such as JWST should have an equally extraordinary name.

- It is not too late to change the name, and in the mean time we have agency in how we refer to JWST in speech and in writing.

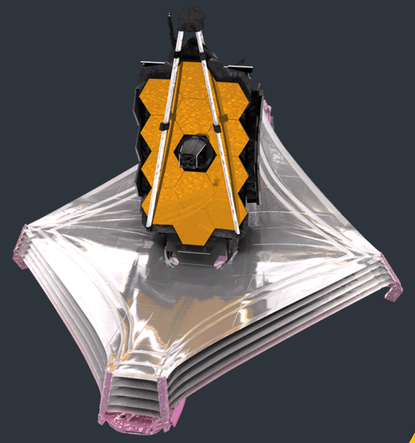
*Further Resources:* *https://notnotrocketscience.substack.com/p/the-straights-are-here-to-save-us?s=r*
*https://www.scientificamerican.com/article/nasa-needs-to-rename-the-james-webb-space-telescope/*
*https://galileospendulum.org/2021/05/07/the-lavender-scare-and-a-tangled-webb/*
*https://astrobites.org/2021/12/19/jwst_renaming/*

Introduction to JWST ERS



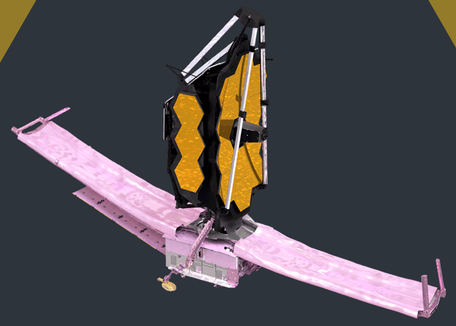
Transiting Exoplanet ERS Program

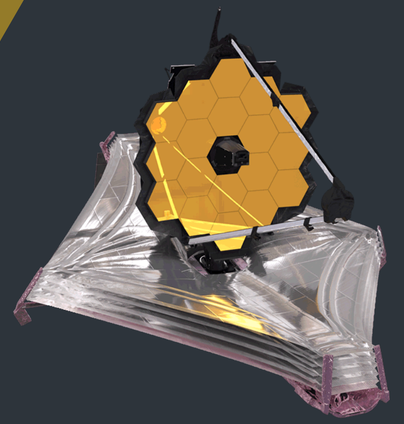
Direct Imaging Exoplanet ERS Program



What's In A Name?

Conclusions





# Transits - Okay, but when?

| Targets | Template | Hours | Plan Windows |
|---|---|---|---|
| WASP-39 | NIRISS Single-Object Slitless Spectroscopy | 10.67 | Jul 22, 2022 - Jul 22, 2022 (2022.203 - 2022.203) |
| WASP-39 | NIRCam Grism Time Series | 10.45 | Jul 18, 2022 - Jul 18, 2022 (2022.199 - 2022.199) |
| WASP-39 | NIRSpec Bright Object Time Series | 10.50 | Jul 14, 2022 - Jul 14, 2022 (2022.195 - 2022.195) |
| WASP-39 | NIRSpec Bright Object Time Series | 10.52 | Jul 10, 2022 - Jul 10, 2022 (2022.191 - 2022.191) |
| WASP-43 | MIRI Low Resolution Spectroscopy | 31.69 | Nov 28, 2022 - Nov 28, 2022 (2022.332 - 2022.332) |
| WASP-18 | NIRISS Single-Object Slitless Spectroscopy | 8.74 | Aug 10, 2022 - Aug 11, 2022 (2022.222 - 2022.223) |

# High Contrast - Okay, but when?

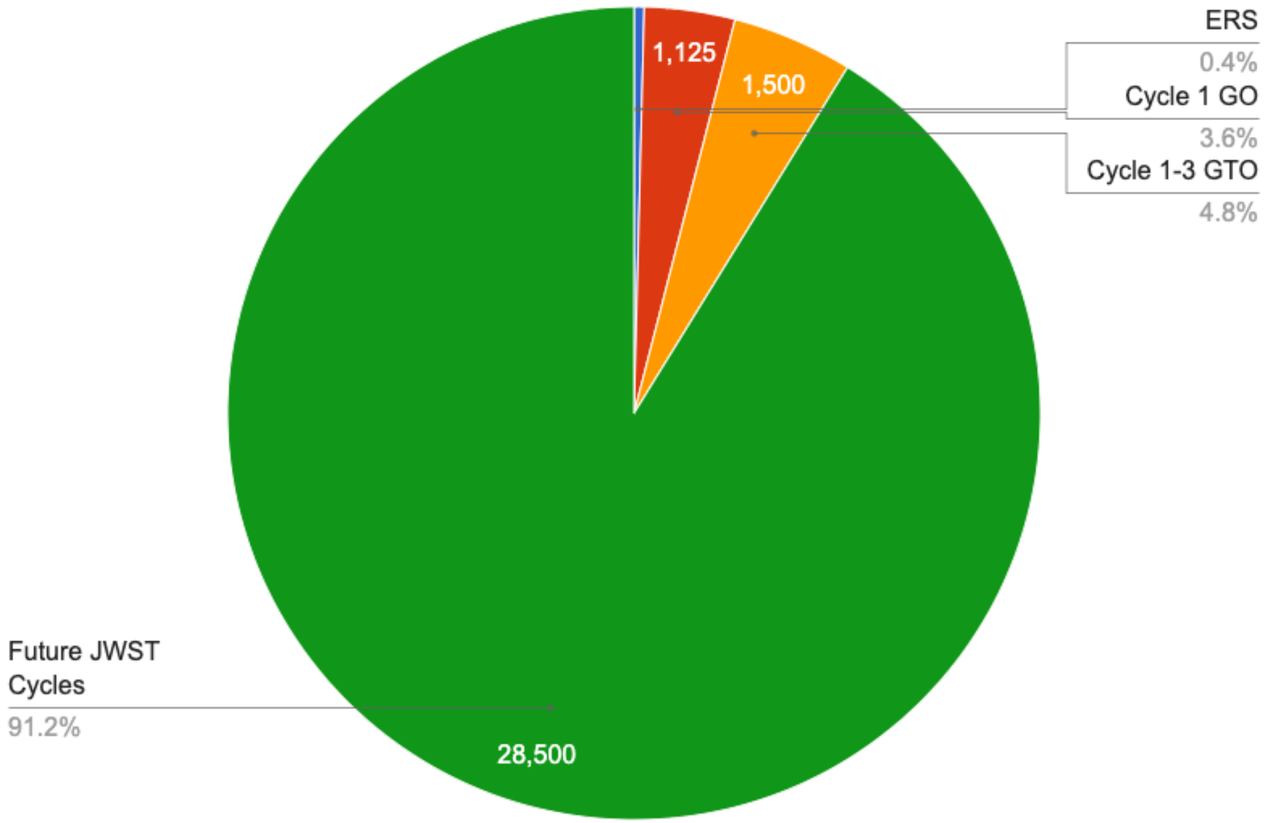
| Targets | Template | Plan Windows |
|---|---|---|
| HIP-65426 | NIRCam Coronagraphic Imaging | Jul 1, 2022 - Jul 16, 2022 (2022.182 - 2022.197)<br>Jul 17, 2022 - Jul 24, 2022 (2022.198 - 2022.205)<br>Jul 26, 2022 - Jul 29, 2022 (2022.207 - 2022.210)<br>Jul 31, 2022 - Aug 2, 2022 (2022.212 - 2022.214)<br>Aug 5, 2022 - Aug 7, 2022 (2022.217 - 2022.219) |
| HIP-65426 | MIRI Coronagraphic Imaging | Jul 4, 2022 - Jul 23, 2022 (2022.185 - 2022.204) |
| HIP-65426 | NIRISS Aperture Masking Interferometry | Jul 1, 2022 - Jul 16, 2022 (2022.182 - 2022.197)<br>Jul 17, 2022 - Jul 24, 2022 (2022.198 - 2022.205)<br>Jul 26, 2022 - Jul 29, 2022 (2022.207 - 2022.210)<br>Jul 31, 2022 - Aug 3, 2022 (2022.212 - 2022.215)<br>Aug 5, 2022 - Aug 8, 2022 (2022.217 - 2022.220) |
| VHS-1256B | NIRSpec IFU Spectroscopy | Jul 1, 2022 - Jul 15, 2022 (2022.182 - 2022.196) |
| VHS-1256B | MIRI Medium Resolution Spectroscopy | Jul 1, 2022 - Jul 15, 2022 (2022.182 - 2022.196) |
| HD-141569A | NIRCam Coronagraphic Imaging | Jul 10, 2022 - Aug 24, 2022 (2022.191 - 2022.236) |
| HD-141569A | MIRI Coronagraphic Imaging | Jul 12, 2022 - Aug 4, 2022 (2022.193 - 2022.216) |

Exoplanet ERS (Cycle 1)
= ~125 hours

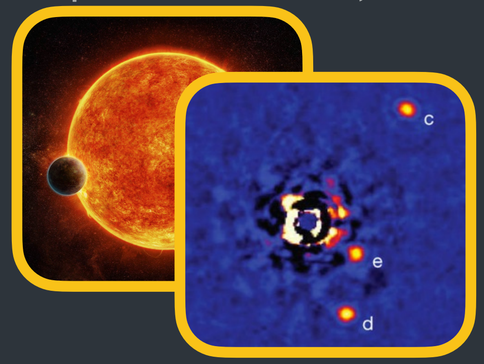
Exoplanet GTO (Cycle 1-3)
= ~1125 hours

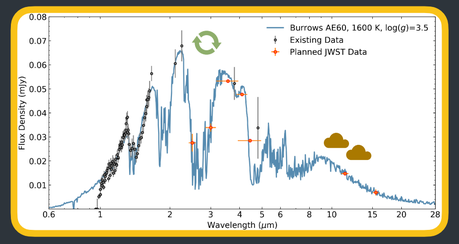
Exoplanet GO (Cycle 1)
= ~1500 hours

Future Exoplanet Observations (Until 2042)
= ~28,500 hours



- **JWST presents an unprecedented opportunity to characterise a diverse range of exoplanets** across their full luminous wavelength ranges through both direct imaging and transiting observations.




- Though focused on informing the community on the capabilities of JWST, **the ERS programs will make the first steps in this era of discovery** with their own clearly defined scientific goals.

- The ERS programs will deliver a wide range of **science enabling products** to the community to aid with proposal planning, data reduction and interpretation.

GitHub

- If you haven’t already, set aside some time to **research the implications of the naming of JWST.** Think about how you can help mitigate the ongoing damage it is causing.