

# Multi-mission multi-instrument data analysis software for exoplanet exploration

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Program: Strategic

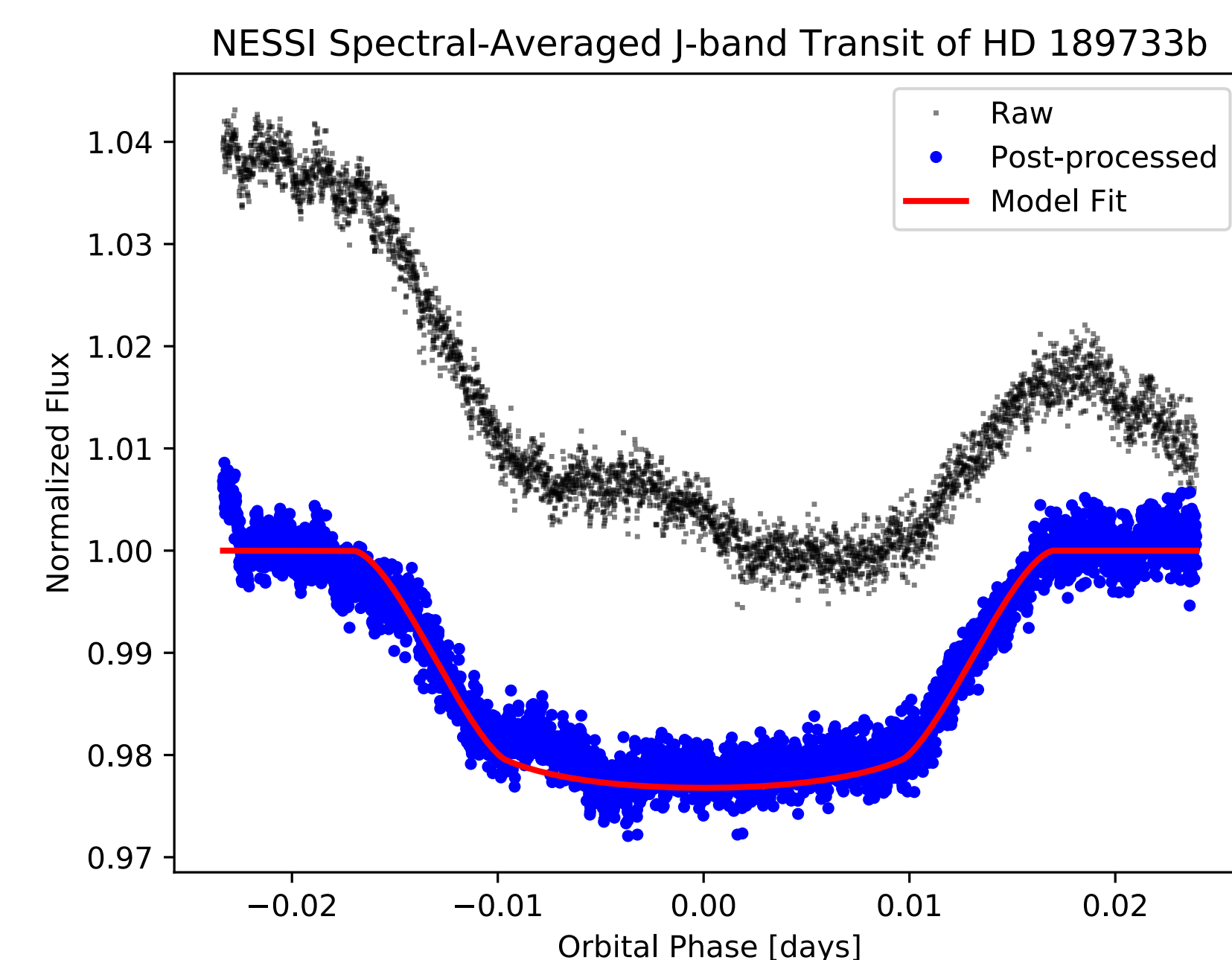
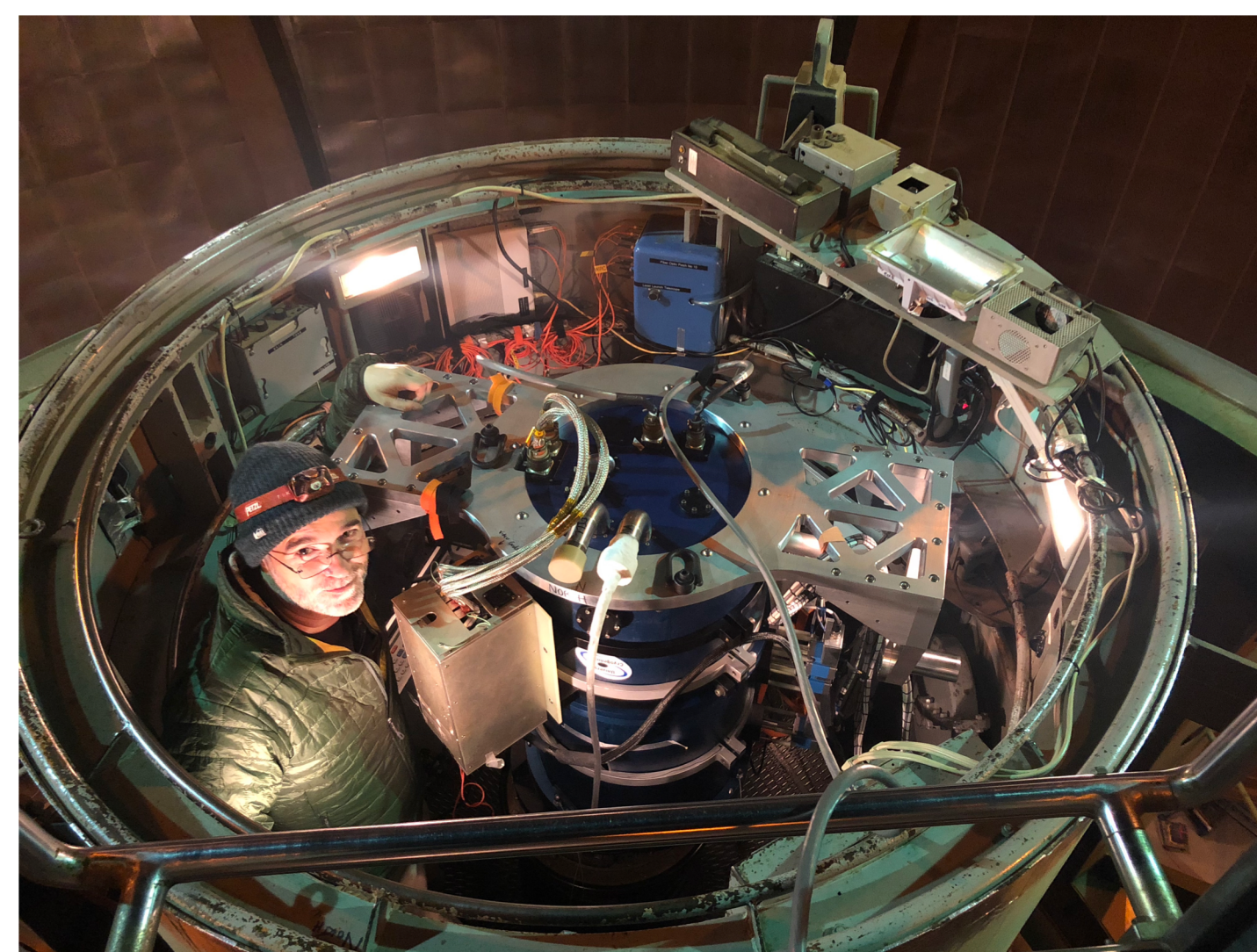
EXCALIBUR (Exoplanet CALibration and Bayesian Unified Retrieval) is a novel science data pipeline designed to always provide the current best estimate of science data products. EXCALIBUR is event driven where the events are defined as changes in data or algorithms; when events are detected, dependencies affected by the change dependencies are automatically re-processed. EXCALIBUR implements statistical metrics and a unified marginalization over both science and instrument model parameters coupled with a Bayesian, evidence-based, model selection capability.

## Task Objectives:

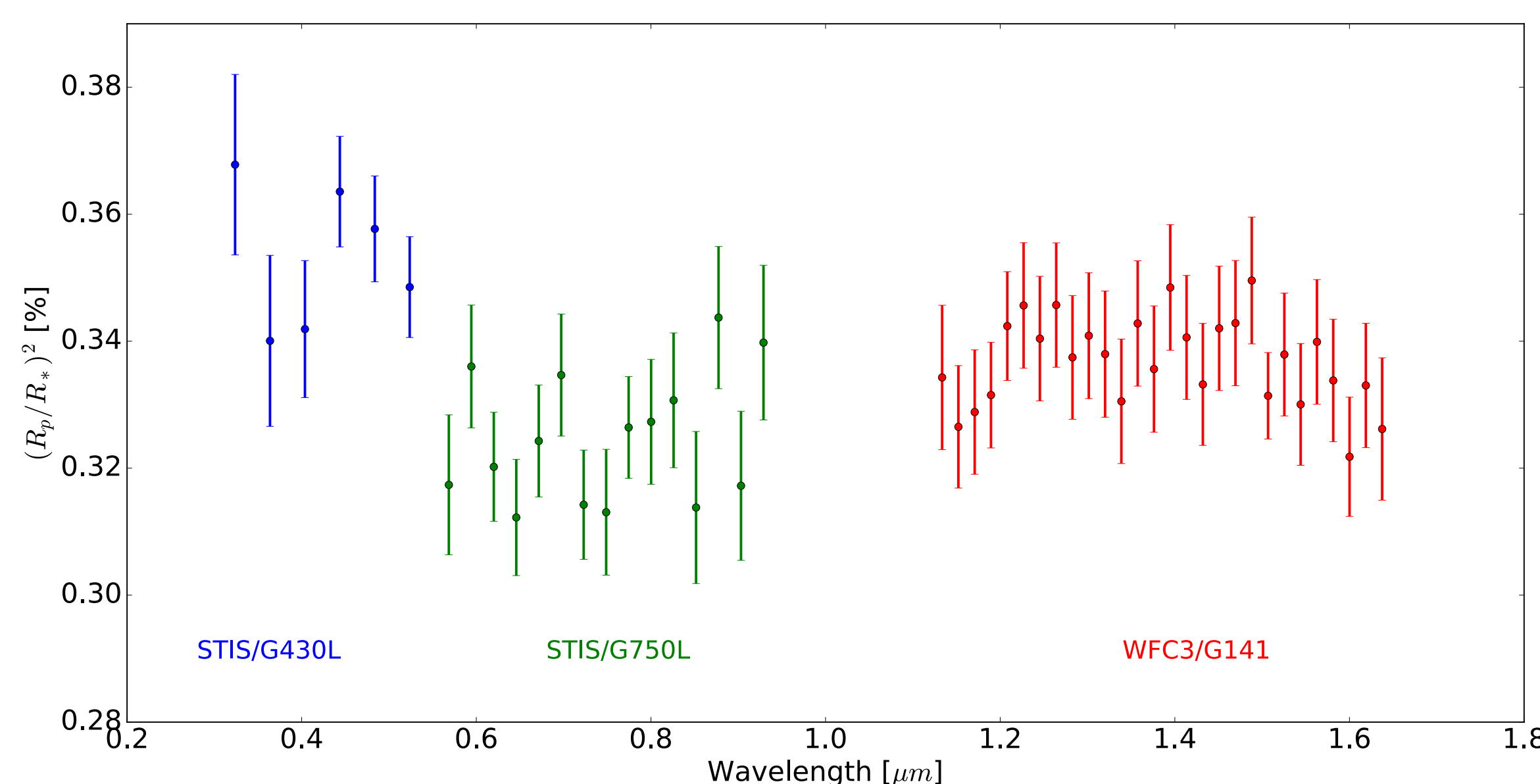
1. upgrade EXCALIBUR for multi-mission, multi-instrument capability, specifically focusing on JWST instruments and enabling Hubble and Spitzer instruments.
2. Commission NESSI instrument for exoplanet science operations on the Palomar 200 inch telescope.

## 2018 Task Results:

- Extraction tools created for all 11 JWST instrument/mode combinations used in the JWST exoplanet Early Release Science (ERS) science observations
- Generalization of EXCALIBUR infrastructure facilitated work to incorporate Hubble STIS and Spitzer IRAC instruments.
- NESSI upgraded and successfully observes exoplanet transit on 11 September 2019.



**Above left:** NESSI instrument installed at prime focus on the Palomar 200 inch telescope (human to left of instrument for scale). **Above right:** near-infrared NESSI observations of the transiting hot-Jupiter exoplanet HD 189733 b use the instrument's slitless wide field capability for high-precision spectrophotometry.

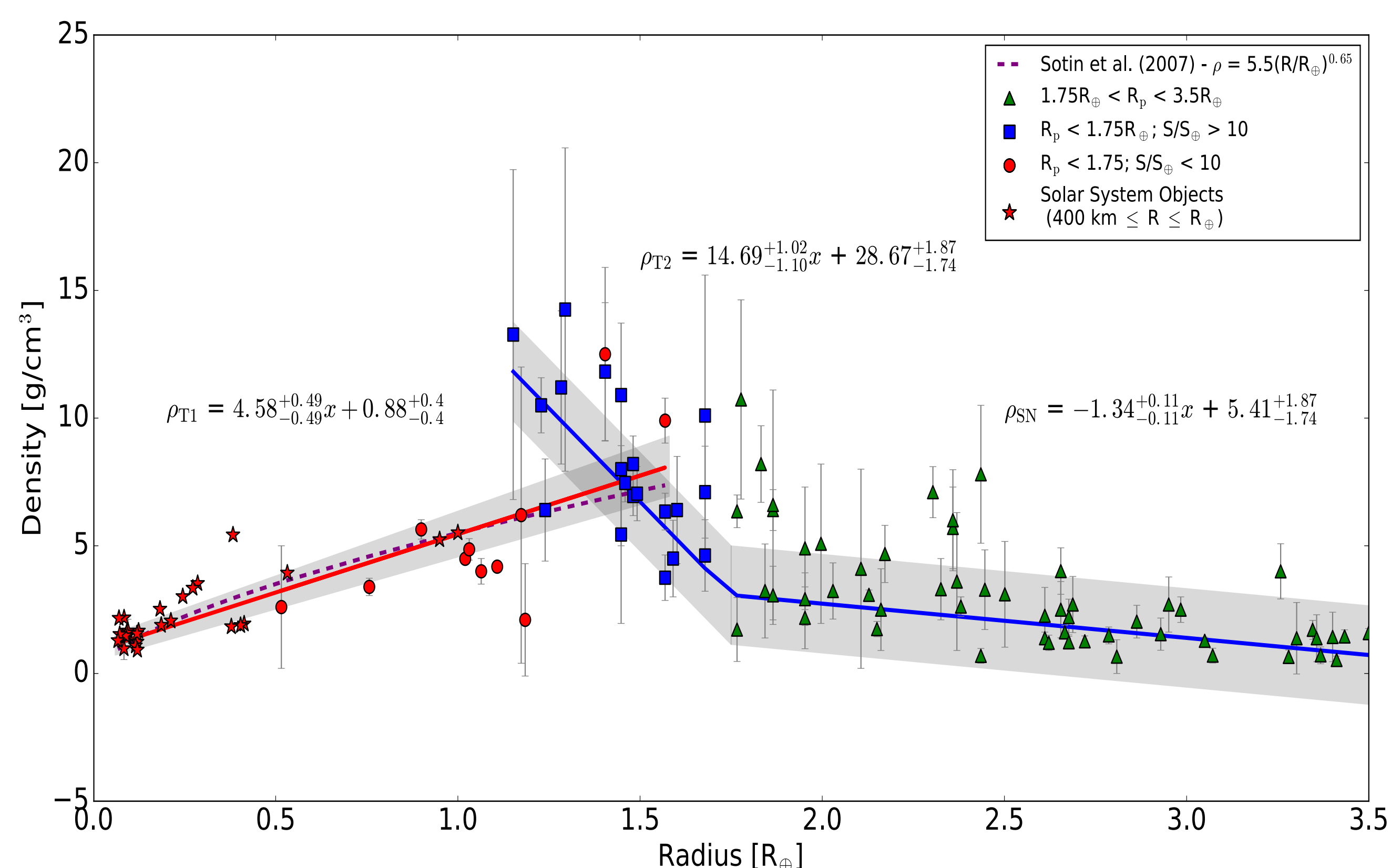


**Left:** A multi-instrument spectrum (Hubble STIS and WFC3) of the exoplanet HAP-P-11 b, which is twice the mass of Neptune.

| Extraction Tools Developed for JWST Early Release Science Observations |            |                  |
|--|------------|------------------|
| Instrument   | Mode       | Selected Example |
| NIRISS 0.6-2.5 μm  | --         |                  |
| NIRCam 0.6-5.0 μm  | F277W      |                  |
|  | F322W      |                  |
|  | F356W      |                  |
|  | F444W      |                  |
| NIRSpec 0.6-5.0 μm   | G235M      |                  |
|  | G395M      |                  |
|  | G140M F070 |                  |
|  | G140M F100 |                  |
|  | G140H F070 |                  |
|  | G140H F100 |                  |
| MIRI 4.9-28.8 μm   | G235H      |                  |
|  | G395H      |                  |
| MIRI 4.9-28.8 μm   | LRS        |                  |

## Benefits to NASA:

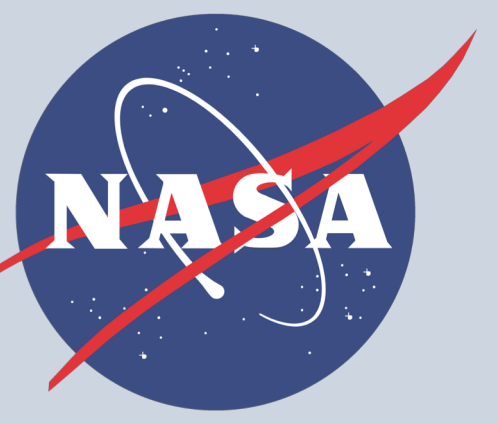
- Uniform joint processing of Hubble/Spitzer/JWST exoplanet observations
- Agile, data products always current
- Enables comparative planetology of exoplanets
- Ground-based follow up of Hubble/Spitzer/TESS/JWST exoplanet discoveries



**Above:** The different density radius relations for insolation selected Terrestrial planets indicates that the low insolation Terrestrial planets are formed by accretion (red), similar to objects in our solar system, while the high insolation Terrestrial planets (blue) are the bare cores of sub-Neptune gas giants that have lost their H/He envelopes.

## Publications:

1. Swain, M. R., Estrela, R., Christophe S., Roudier, G. M., Zellem, R. T. "Two Terrestrial Planet Families with Different Origins" 2019 Astrophysical Journal, 881, 117S
2. Zellem, R. T., Swain, M. R., Cowan N. B., Bryden, G. Komacek, T. D. "Constraining Exoplanet Metallicities and Aerosols with the Contribution to ARIEL Spectroscopy of Exoplanets (CASE)" 2019 Publications of the Astronomical Society of the Pacific, 131, 1003
3. Code for three NTRs (49811, 50763, 50770) issued for this task in FY2018 cleared for unlimited release.



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See email August 27  
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