The Roman Galactic Exoplanet Survey

Scott Gaudi
The Ohio State University
On behalf of the Roman Galactic Exoplanet Survey Project Infrastructure Team

National Aeronautics and Space Administration

NASA

Nancy Grace Roman

- Served as NASA's first Chief of Astronomy throughout the 1960s and 1970s
- Known to many as the "Mother of Hubble" for her foundational role in planning the Hubble Space Telescope

Summary of Roman Space Telescope Properties

Properties	Roman
Eff. Aperture	2.28m
FOV	0.281 deg^2
Wavelengths	~0.5-2 μm (WFI)
FWHM@1μm	0.10”
Pixel Size	0.11”
Launch/ Lifetime	2026/5 years
Orbit	L2

Wide-Field Instrument (WFI)

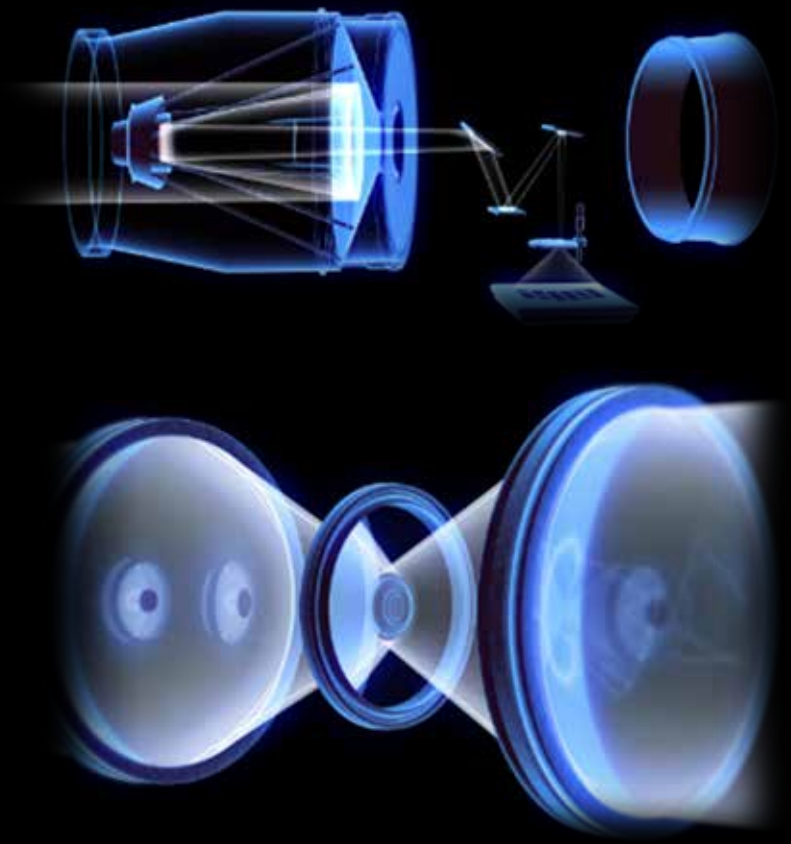
- ~0.5–2.0 micron bandpass
- 0.281 sq. deg. FoV (~100x HST ACS FoV)
- 18 H4RG detectors (288 Mpixels)
- 7 filter imaging, grism and prism spectroscopy

Coronagraph Instrument (CGI)

- Visible (545-865nm) high-contrast imager
- Polarimeter and spectrograph
- 3 types of coronagraph masks
- Two months of tech dev observations.

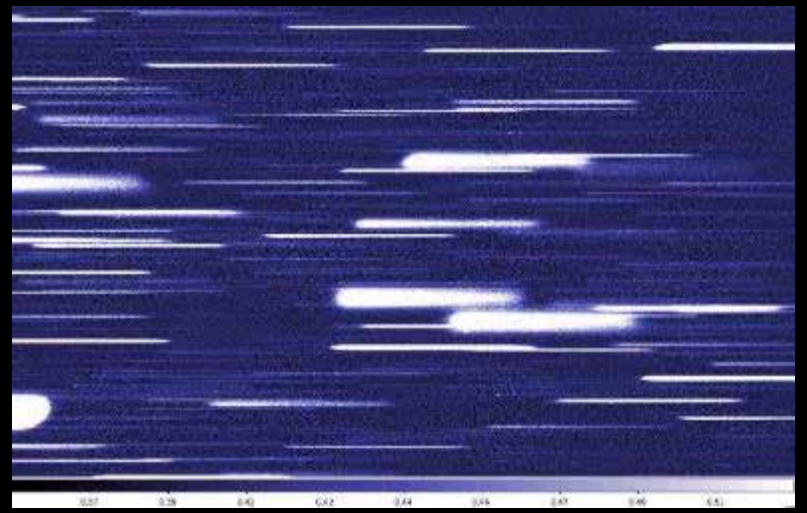
Five Core Community WFI Surveys

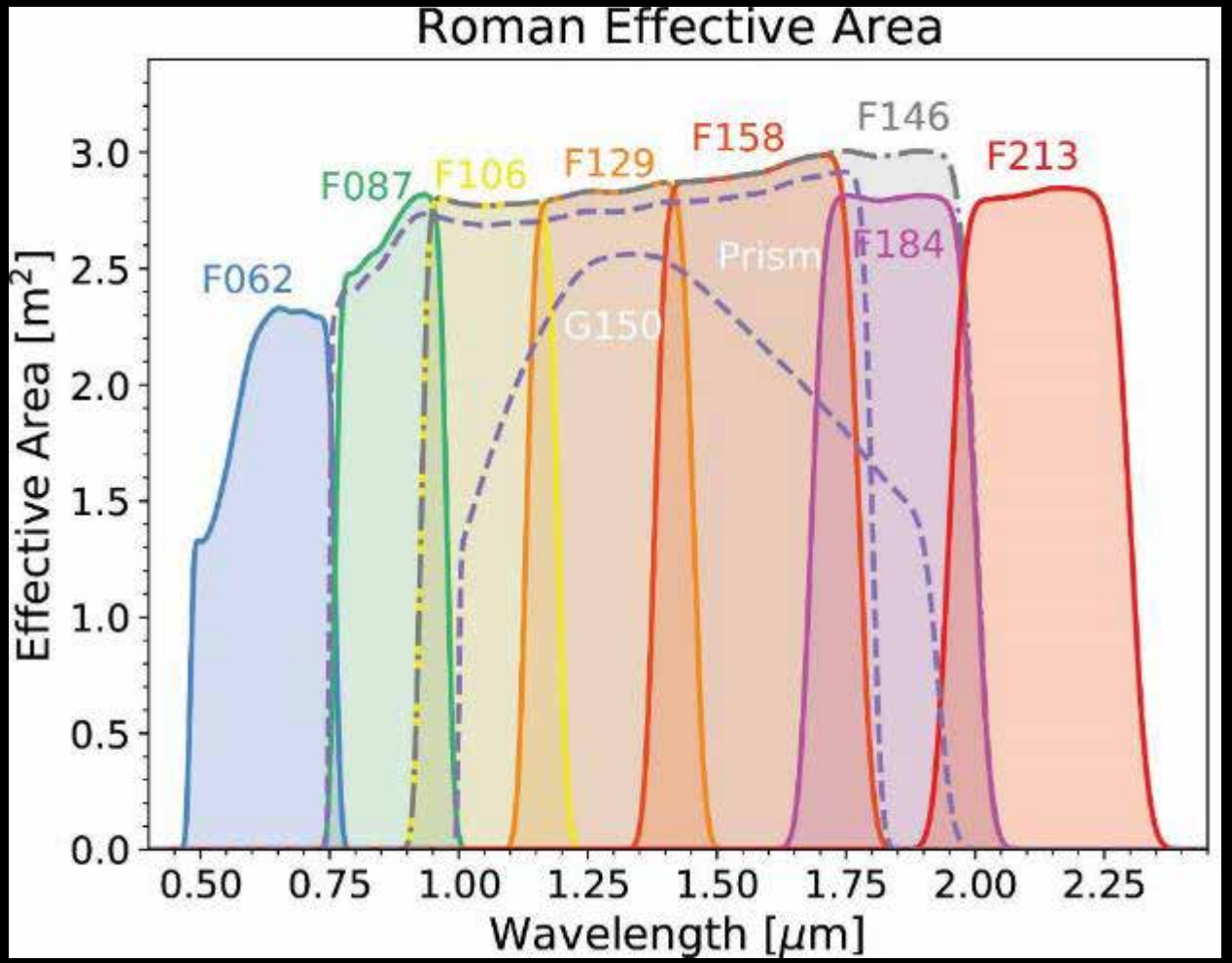
- HL Imaging Survey
- HL Spectroscopy Survey
- SNe survey
- Galactic Bulge Time Domain Survey
- Galactic Plane Survey



Wide Field Imaging Filters and Dispersers

- Seven ~standard imaging filters
- **Wide F146 filter used for the μL survey (~1-2 µm)**
- Grism (1.0 – 1.93 μm, R~600)
- Prism (0.75 –1.80 μm, R~100)



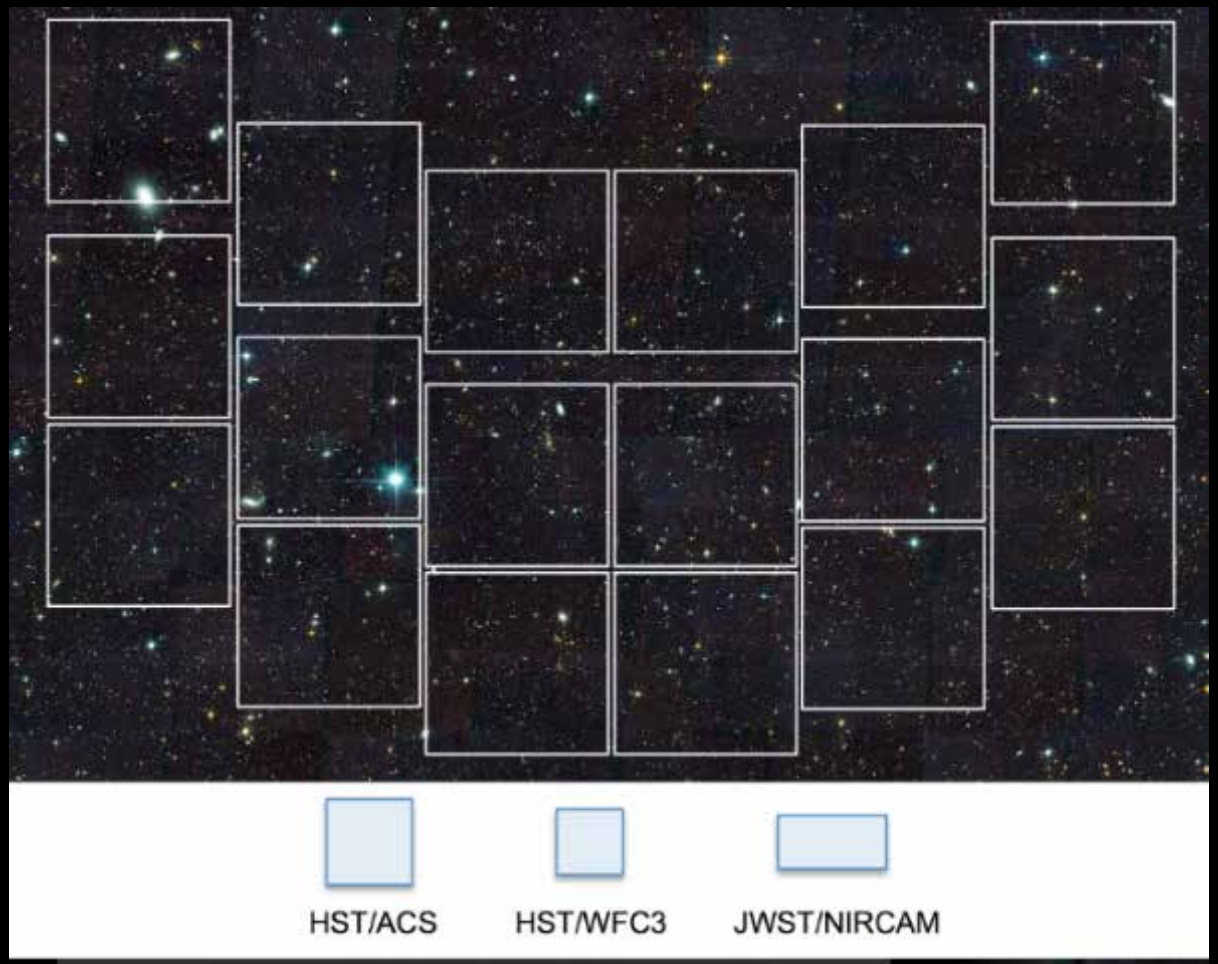


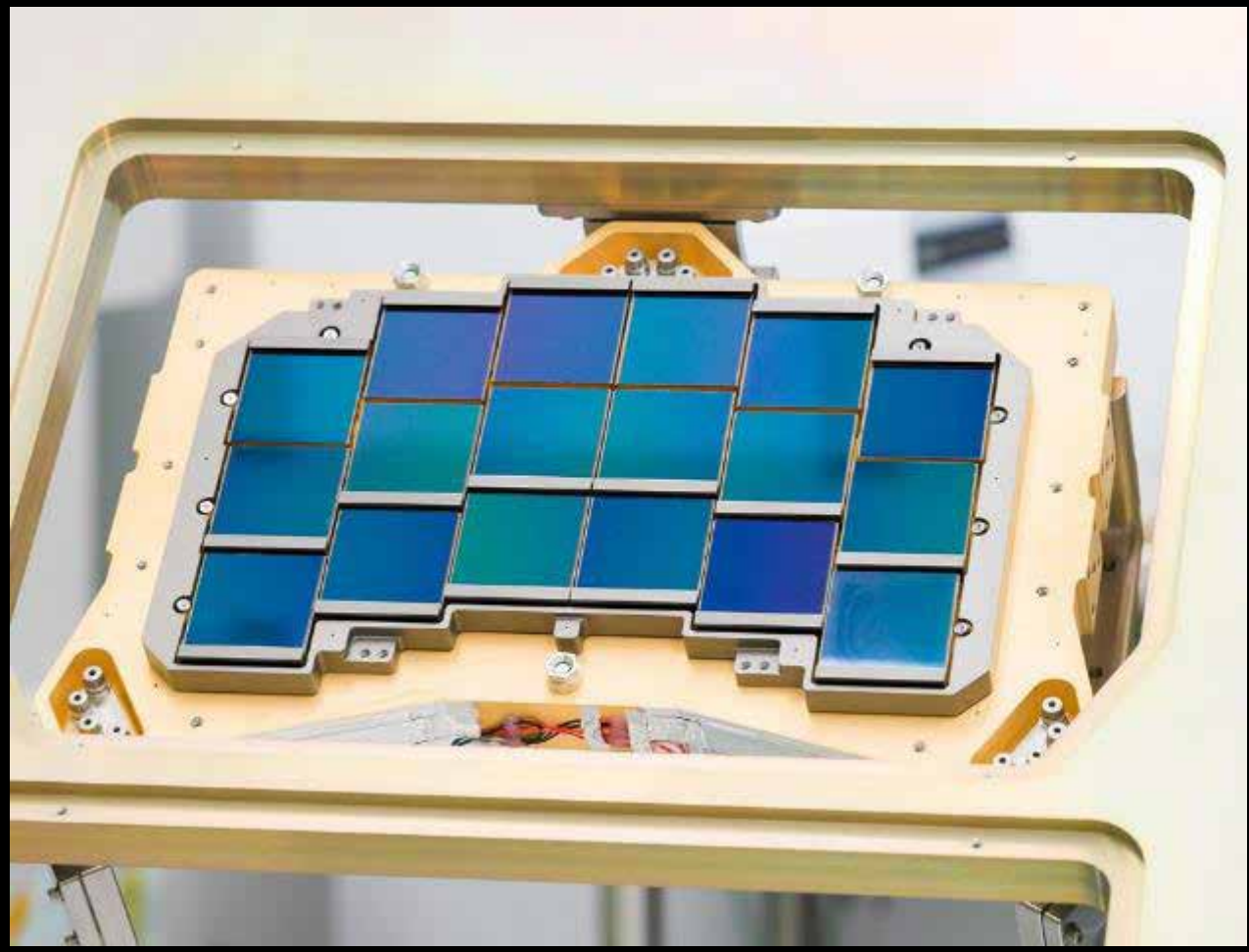
NANCY GRACE ROMAN SPACE TELESCOPE

National Aeronautics and Space Administration

NASA

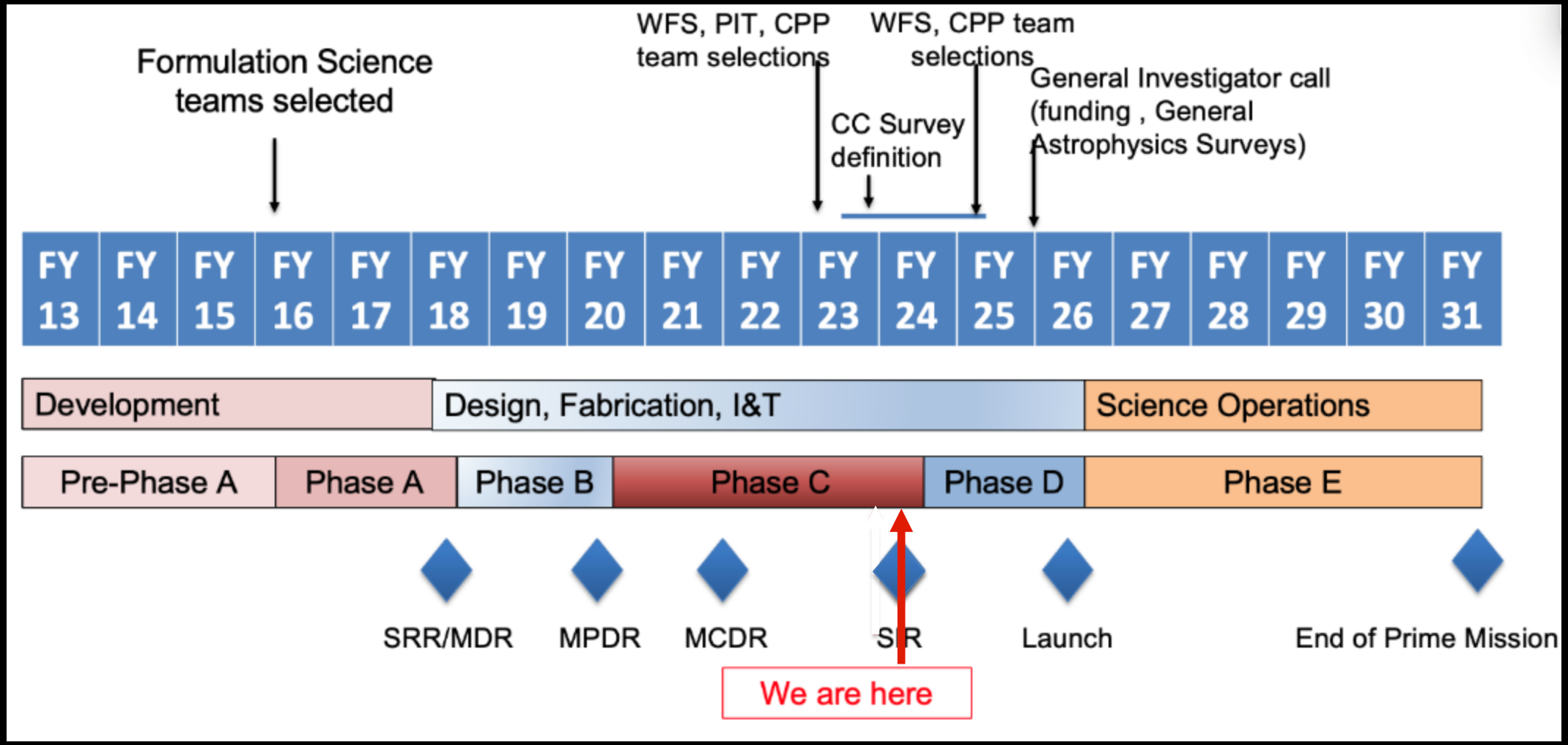
~100 Times the Field-of-View Of Hubble





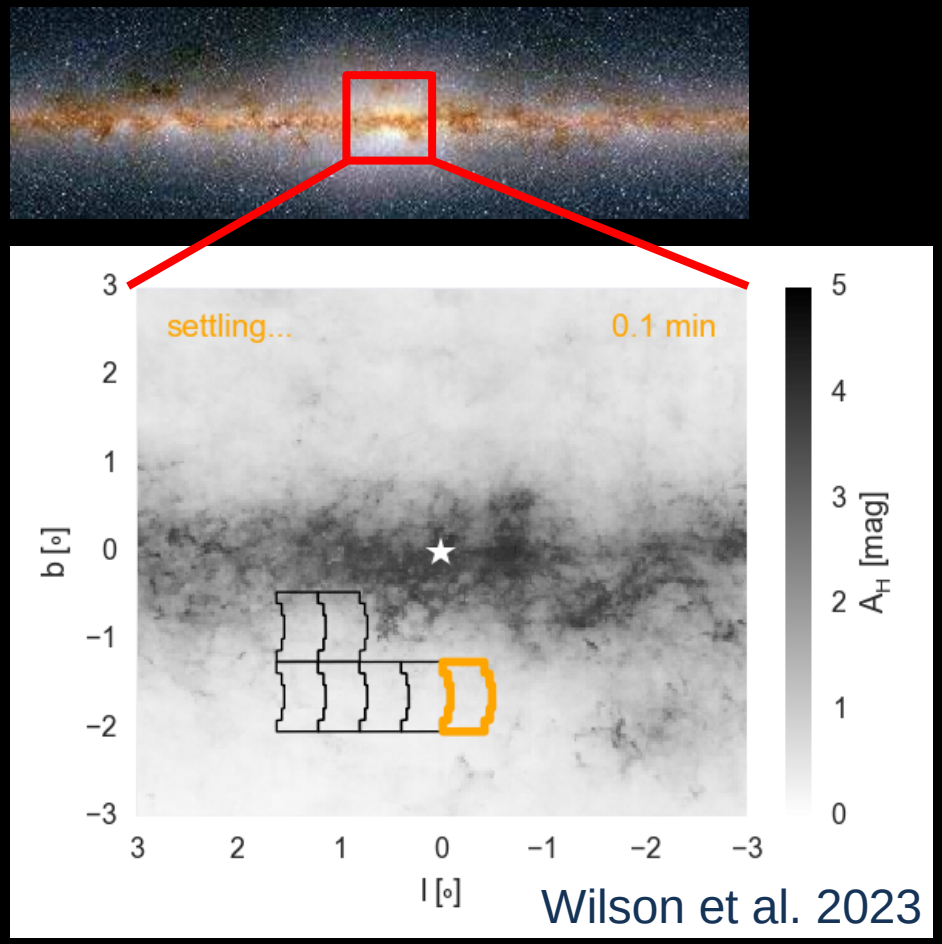
Video: Roman Space Telescope hardware milestones from fall 2023.

Roman Project Timeline



ON TRACK FOR AN OCTOBER 2026 LAUNCH DATE!

Notional* Parameters for the Roman Galactic Bulge Time Domain Survey

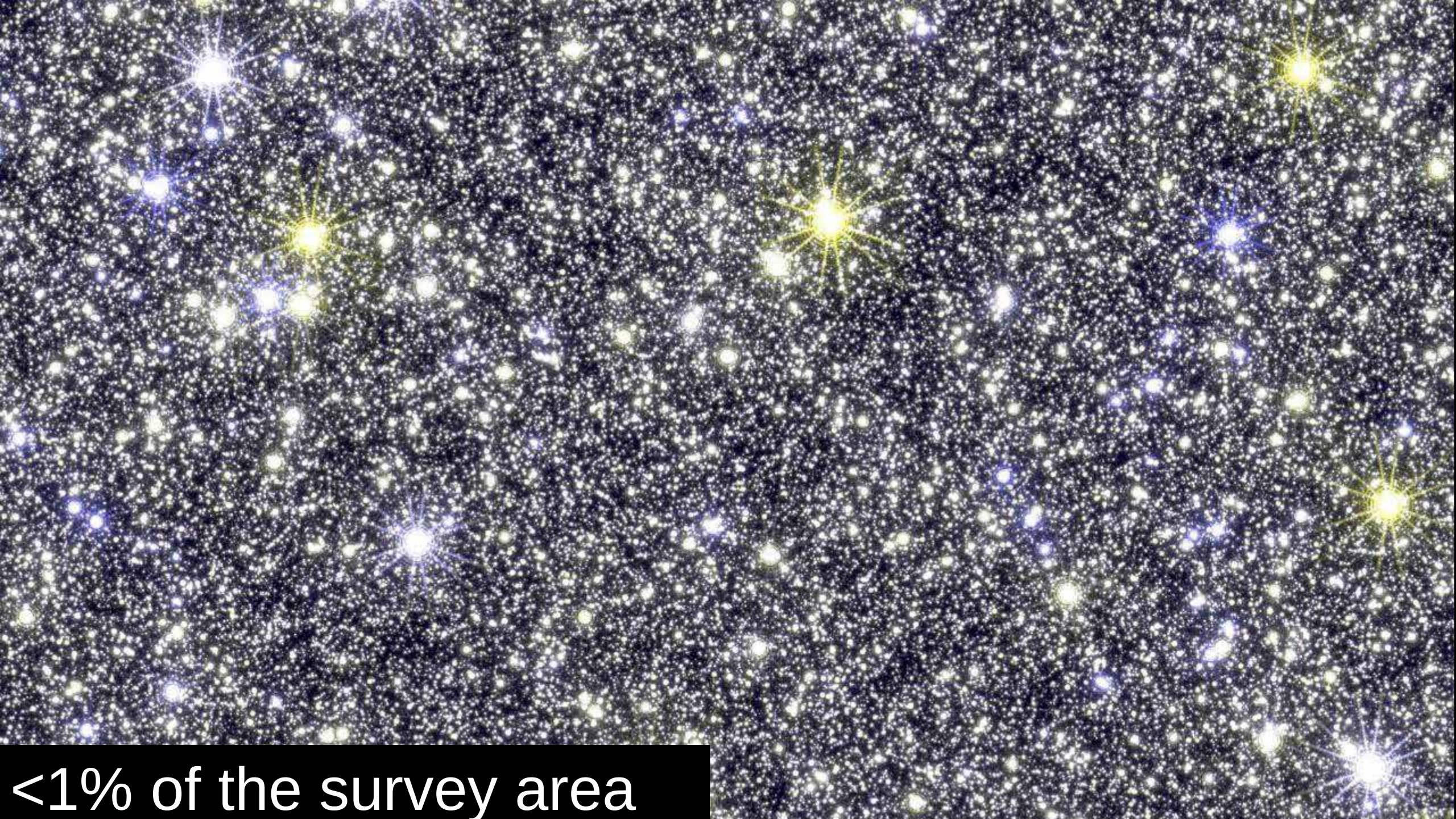


Wilson et al. 2023

- 7 fields for a total of ~2 deg2
- Wide $F146_{AB}$ (0.93-2 μm) filter**.
- 15-minute cadence.
- ~50s exposures.
- Observations every at 6 hours in alternating filters (e.g., F087,F213), 2 x 450 total obs.
- 6 x (62-72) day seasons
- ~41,000 exposures in $F146_{AB}$.
- ~432 total days spread over 5-year mission.

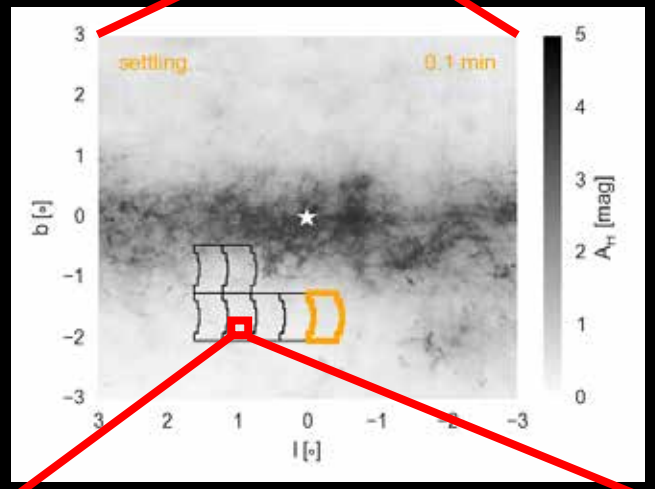
*Notional survey strategy, actual strategy to be determined based on broad community input.

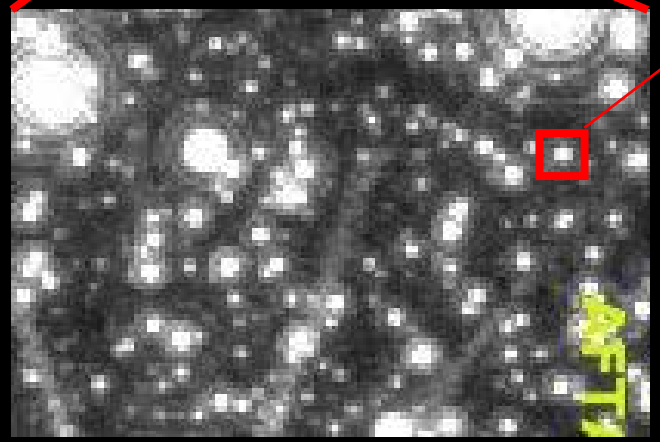
**One photon per second for $F146_{AB}$ ~27.6

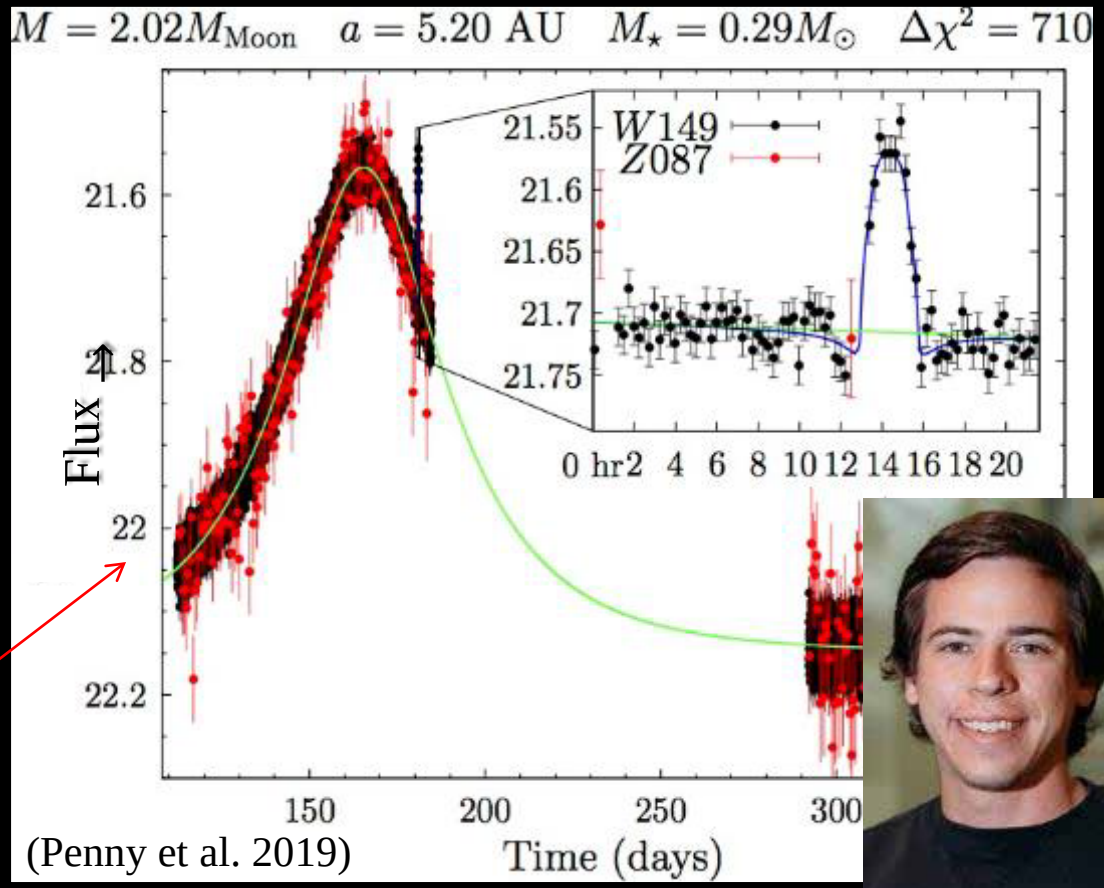

<1% of the survey area

Science Requirements for the GBTDS Survey

- Roman shall be capable of measuring the mass function of exoplanets with masses in the range 1 M_{Earth} < m < 30 $M_{Jupiter}$ and orbital semi-major axes ≥ 1 AU to better than 15% per decade in mass.
- Roman shall be capable of measuring the frequency of bound exoplanets with masses in the range 0.1 M_{Earth} < m < 0.3M_{Earth} to better than 25%
- Roman shall be capable of determining the masses of, and distances to, host stars of 40% of the detected planets with a precision of 20% or better.
- Roman shall be capable of measuring the frequency of free floating planetary-mass objects in the Galaxy from Mars to 10 Jupiter masses in mass. If there is one M_{Earth} free-floating planet per star, measure this frequency to better than 25%.
- Roman shall be capable of estimating η_{Earth} (defined as the frequency of planets orbiting FGK stars with mass ratio and estimated projected semimajor axis within 20% of the Earth-Sun system) to a precision of 0.2 dex via extrapolation from larger and longer-period planets.





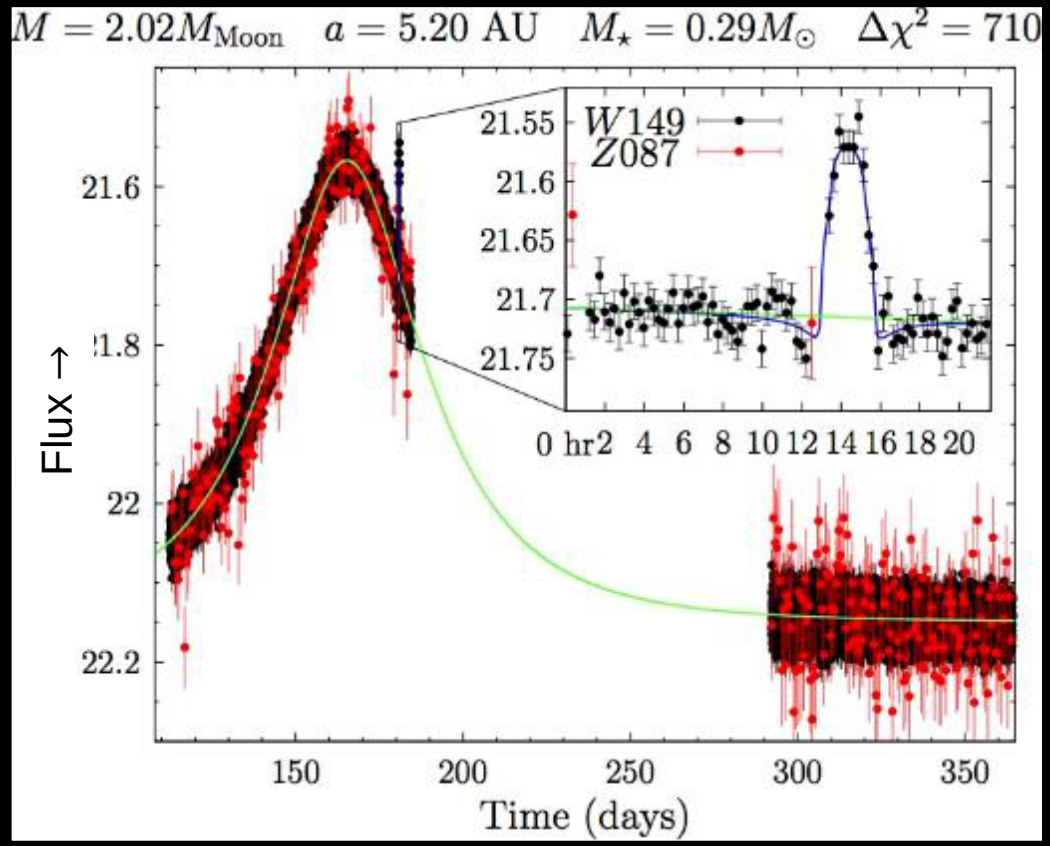


(Penny et al. 2019)

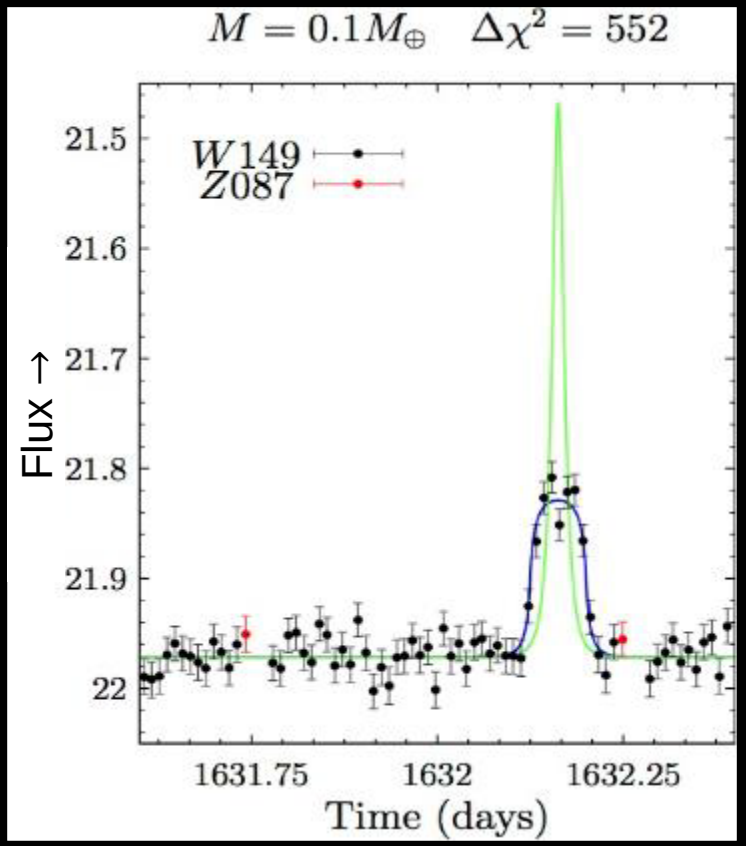
Samson Johnson

Matthew Penny

Simulated Microlensing Planet Detections



2 × Mass of the Moon @ 5.2 AU
(~27 sigma)



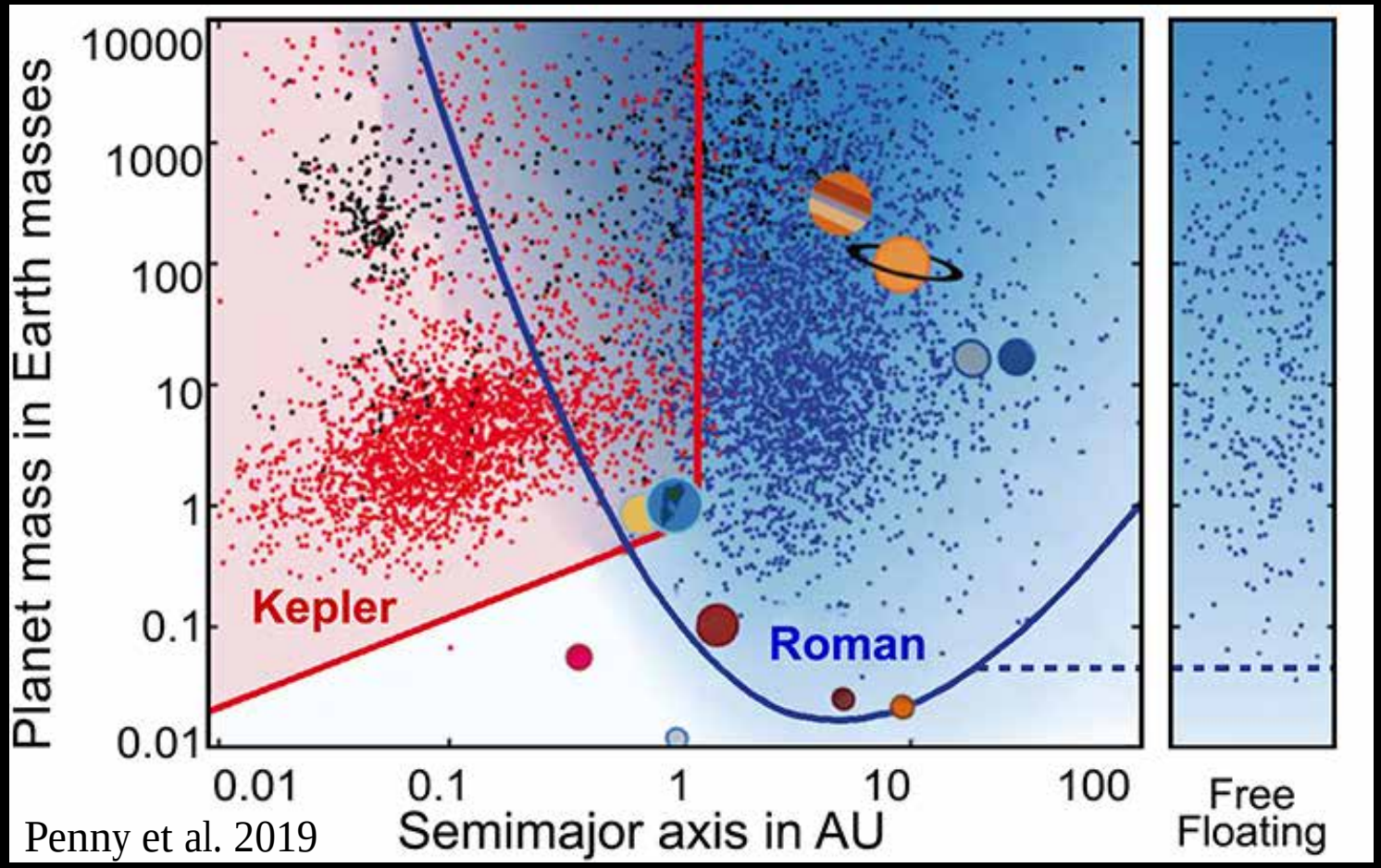
Free floating Mars
(~23 sigma)

Yields for Notional Survey Design

$M/M_\oplus$ / Duration	0.1 -0.3	1	10	100	1000	3000-10000	Total	Free-Floating Earths
432 days	20	181	545	412	224	91	1474	51
(Uncertainty)	(22%)	(7%)	(4%)	(5%)	(7%)	(10%)		(14%)
0.8×432 days	16	144	436	330	179	73	1179	41
(Uncertainty)	(25%)	(8%)	(5%)	(6%)	(7%)	(12%)		(16%)

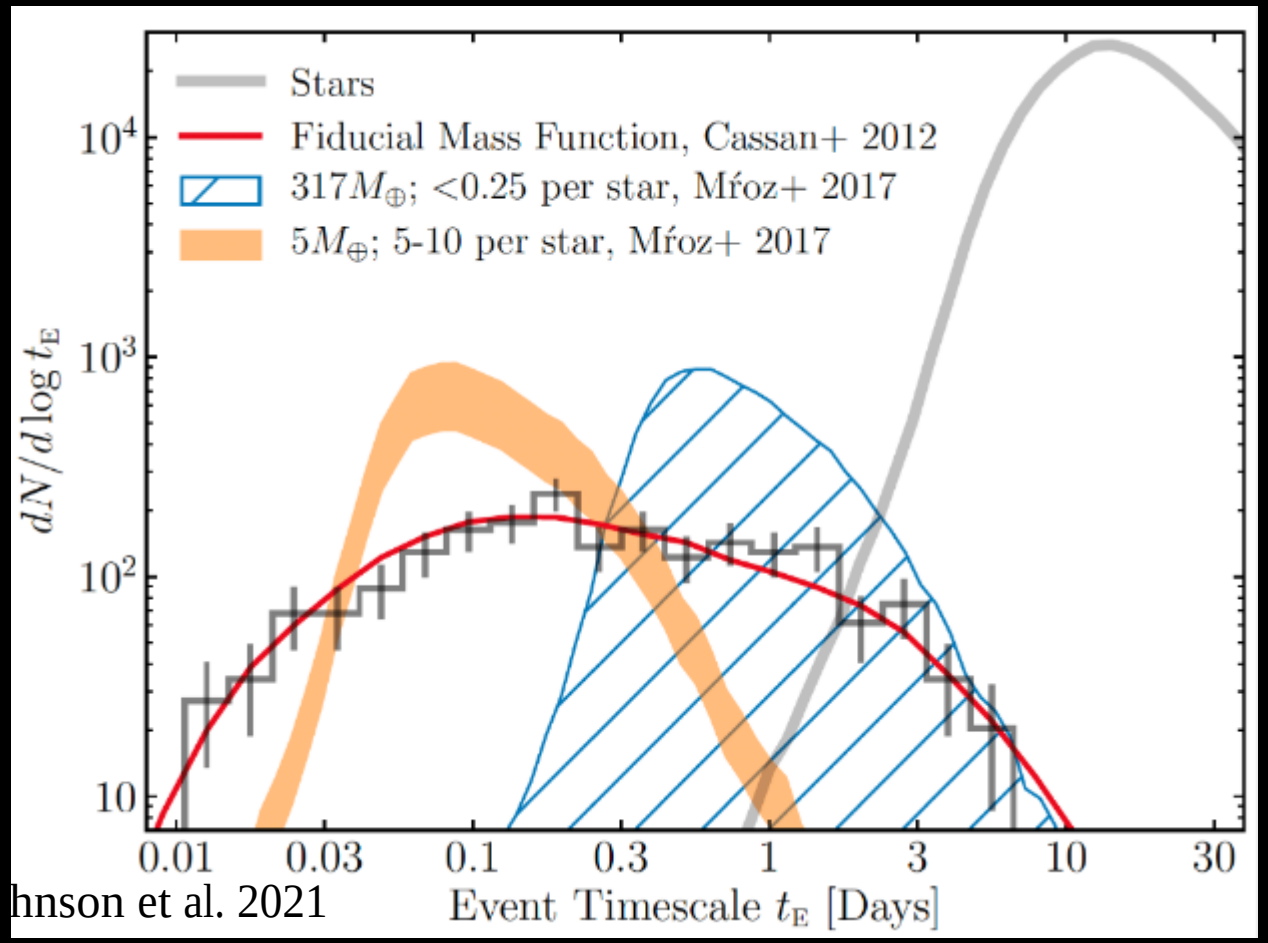
- To first order, yields scale linearly with total survey duration
- The notional survey design (used in the DRM) meets the science requirements with ~20% margin.

A Complete Statistical Census of Exoplanets (a.k.a. the “Penny Plot”)

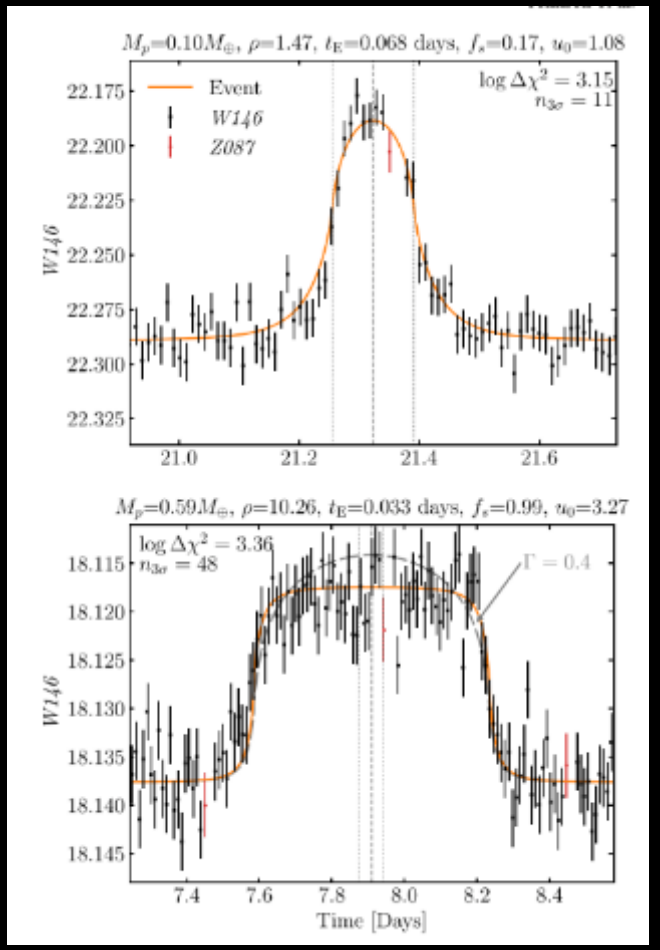


Penny et al. 2019

Predictions for the Yield of FFPs.

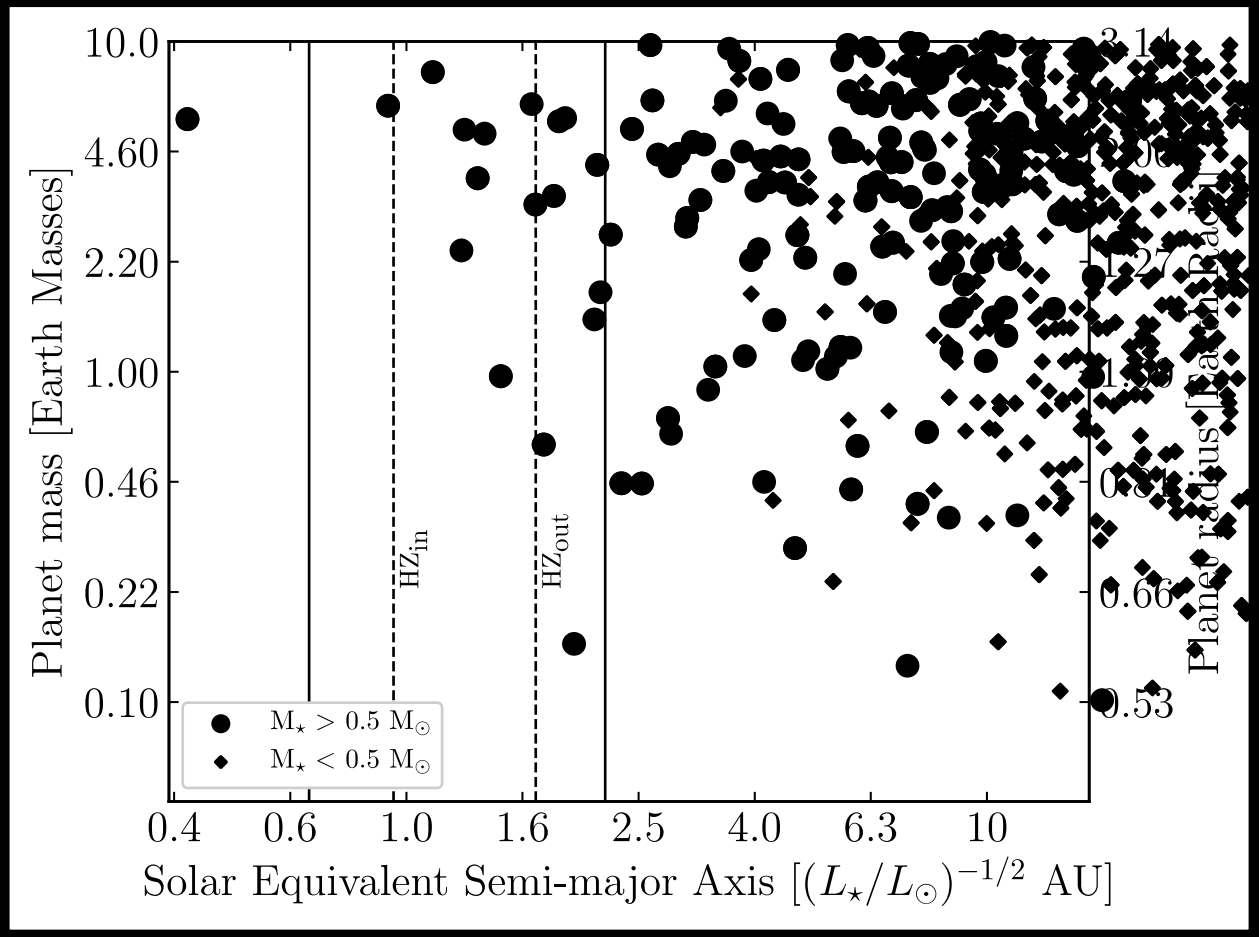


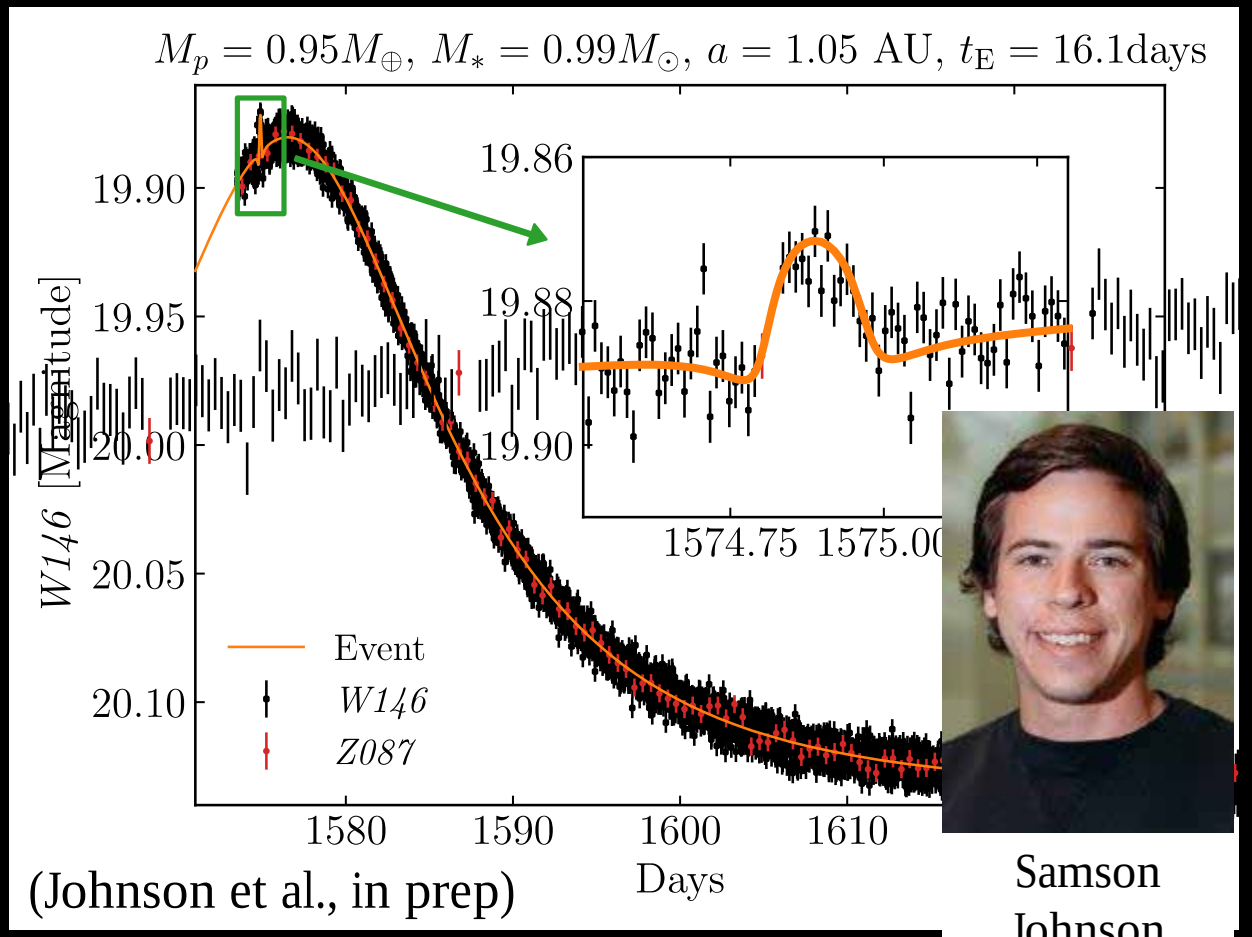
hnson et al. 2021



Samson Johnson

Potentially Habitable Planets



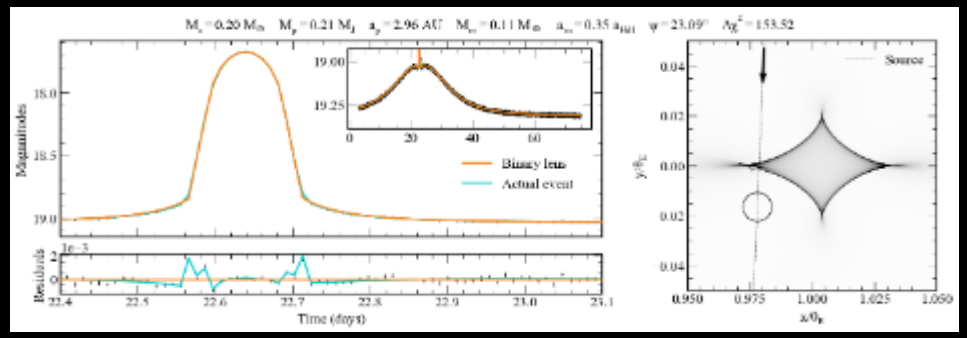


(Johnson et al., in prep)

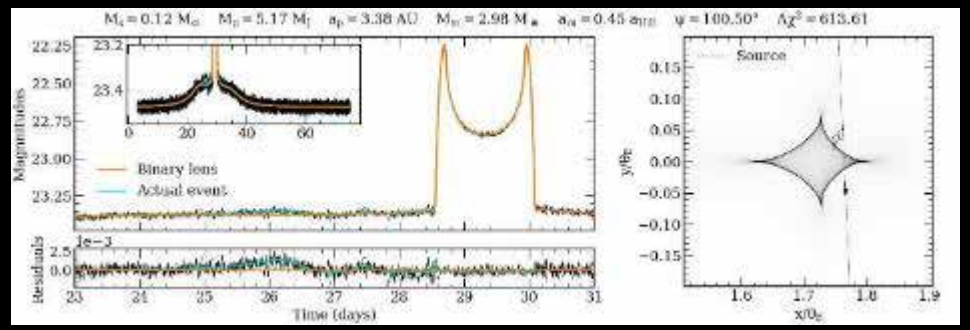
Samson Johnson

Giant Moons

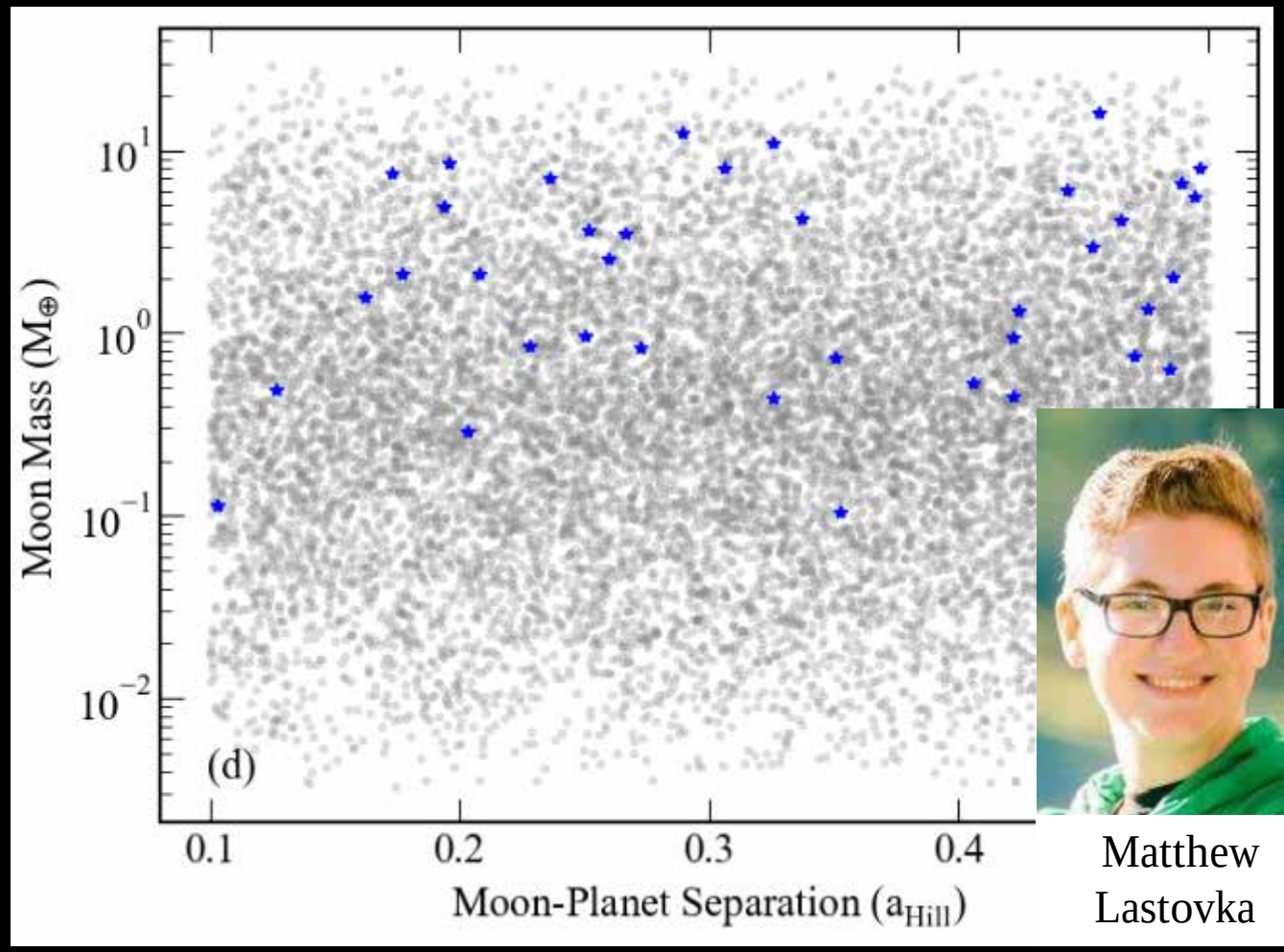
Lastovka et al. in prep



~M_{Mars} moon orbiting 0.35 Hill radii from a ~Saturn-mass planet at ~2.69 AU



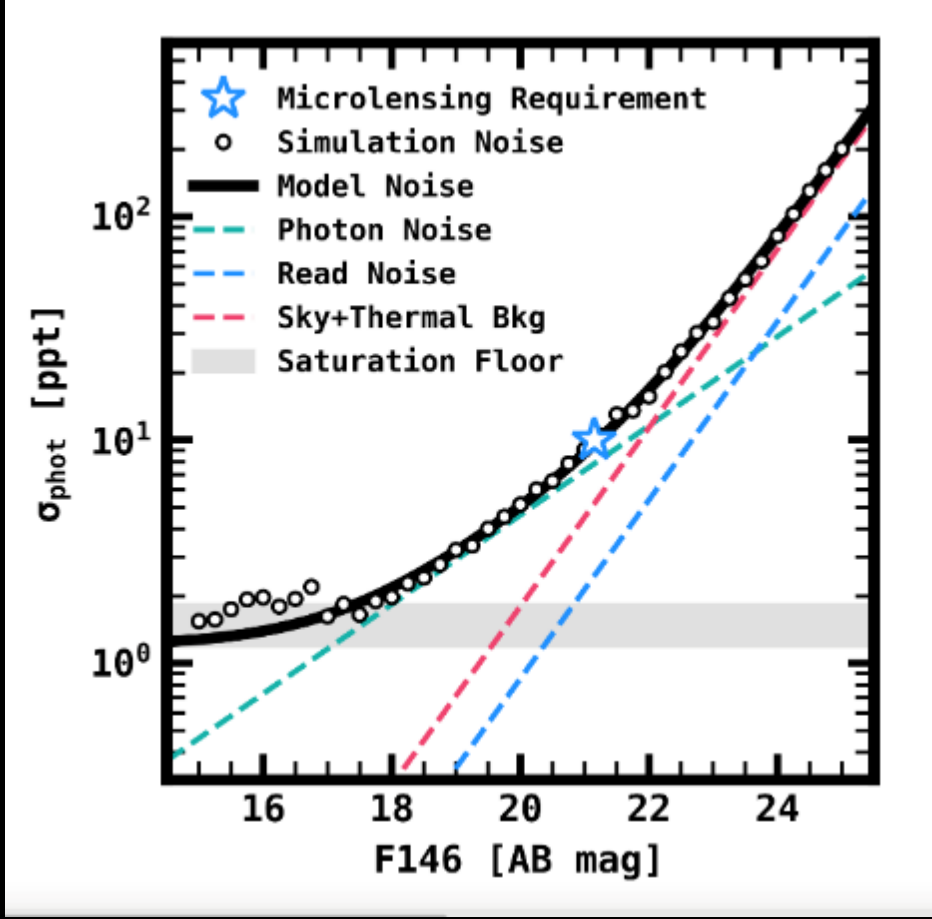
~$3M_{Earth}$ moon orbiting 0.45 Hill radii from a ~5xJupiter-mass planet at ~3.38 AU



Matthew Lastovka

Statistical Power of the RGBTDS

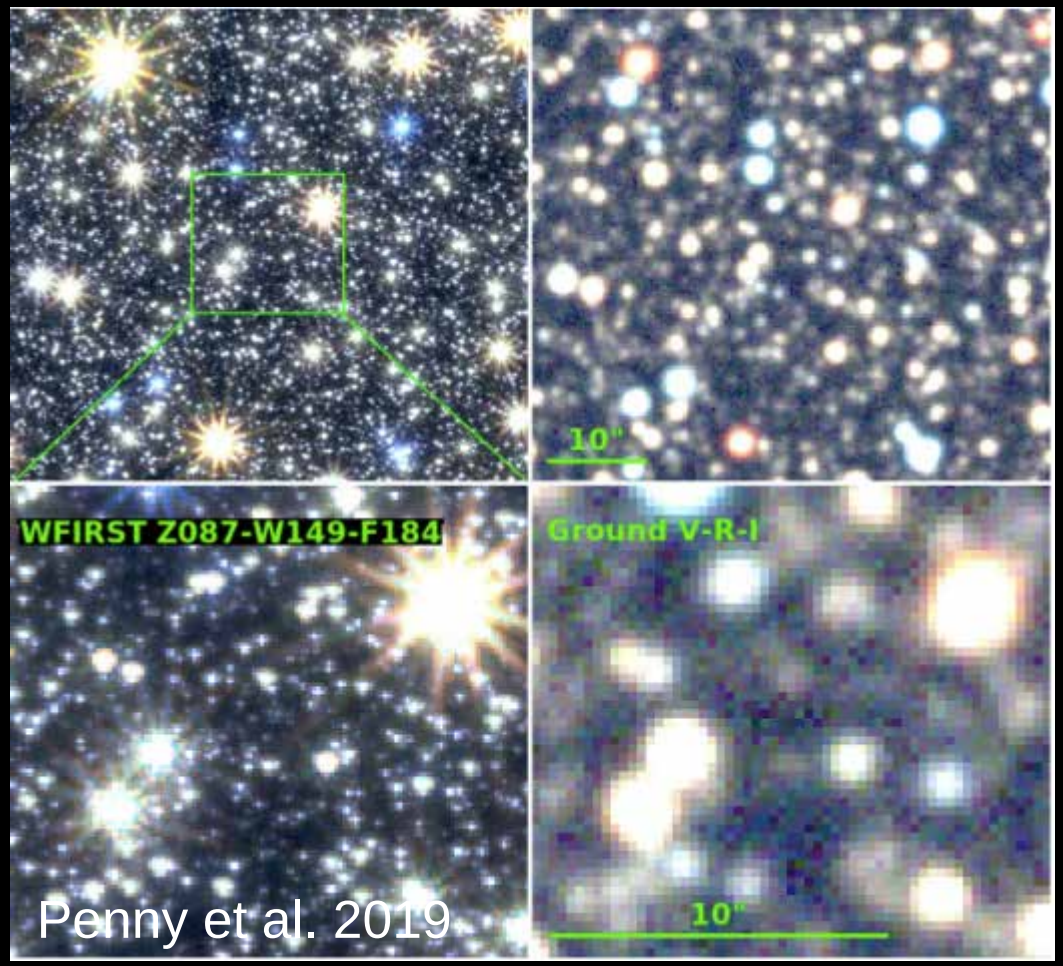
Wilson et al. 2023



For a $F146_{AB}$~21.15 star:

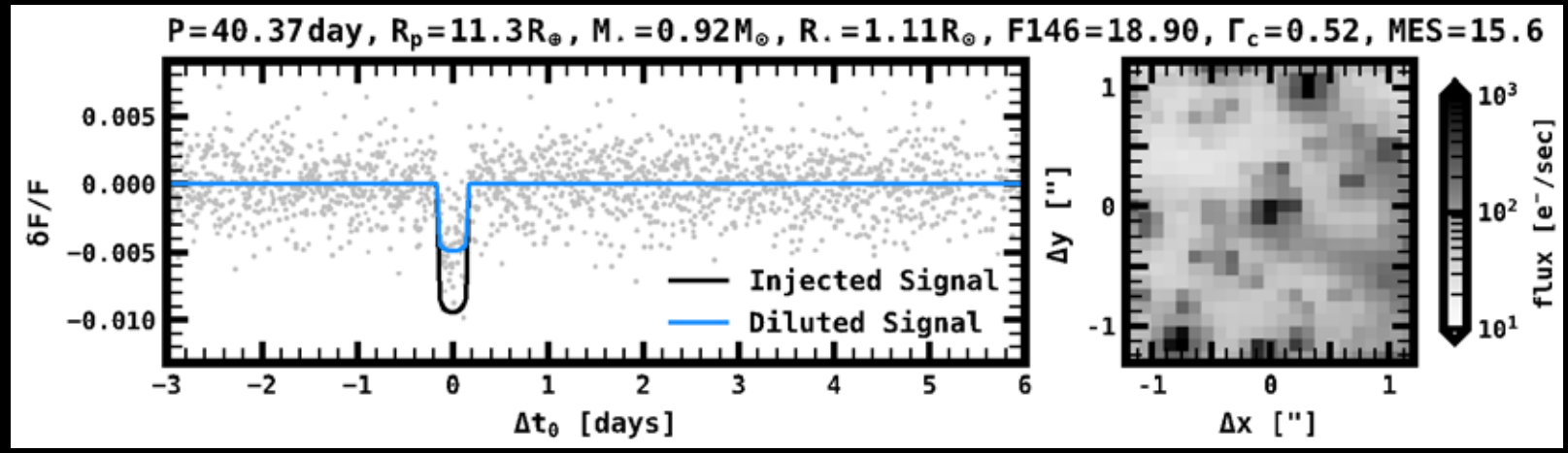
- Photometric precision of σ~0.01 mag per exposure.
- Astrometric precision of ~1mas mag per exposure
- Total of ~10^9 photons over the survey.
- Saturation @ $F146_{AB}$ ~14.8.
- Root N: $\sqrt[2]{41{,}000}$ ~ 200.

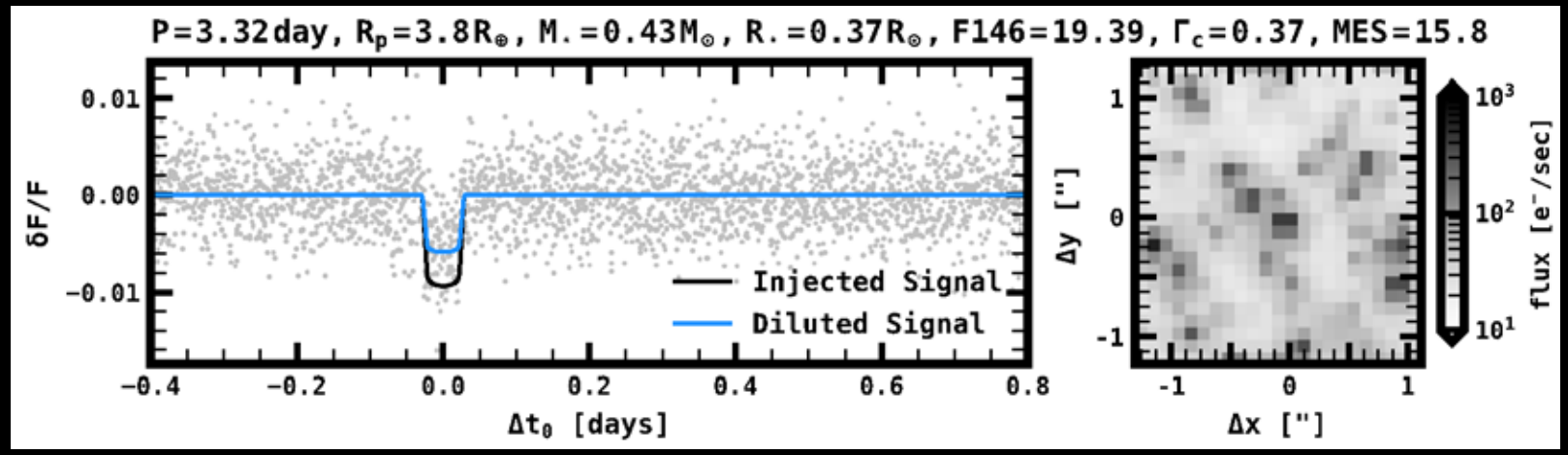
Number of Sources and Microlensing Events



Stars ($W149 < 15$)	$\sim 0.3 \times 10^6$
Stars ($W149 < 17$)	$\sim 1.4 \times 10^6$
Stars ($W149 < 19$)	$\sim 5.8 \times 10^6$
Stars ($W149 < 21$)	$\sim 38 \times 10^6$
Stars ($W149 < 23$)	$\sim 110 \times 10^6$
Stars ($W149 < 25$)	$\sim 240 \times 10^6$
Microlensing events $\lvert u_0 \rvert < 1$	$\sim 27,000$
Microlensing events $\lvert u_0 \rvert < 3$	$\sim 54,000$

Simulated Transit Planet Detections

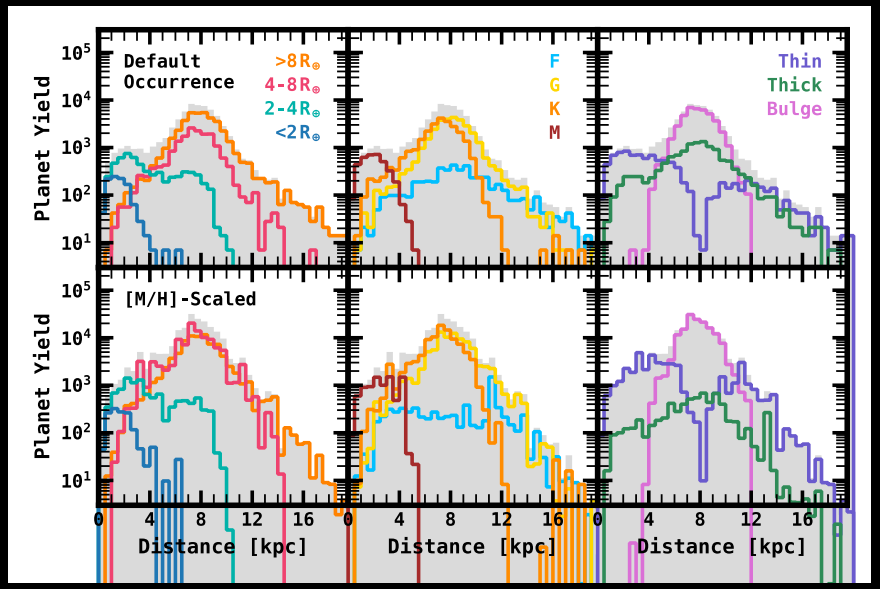


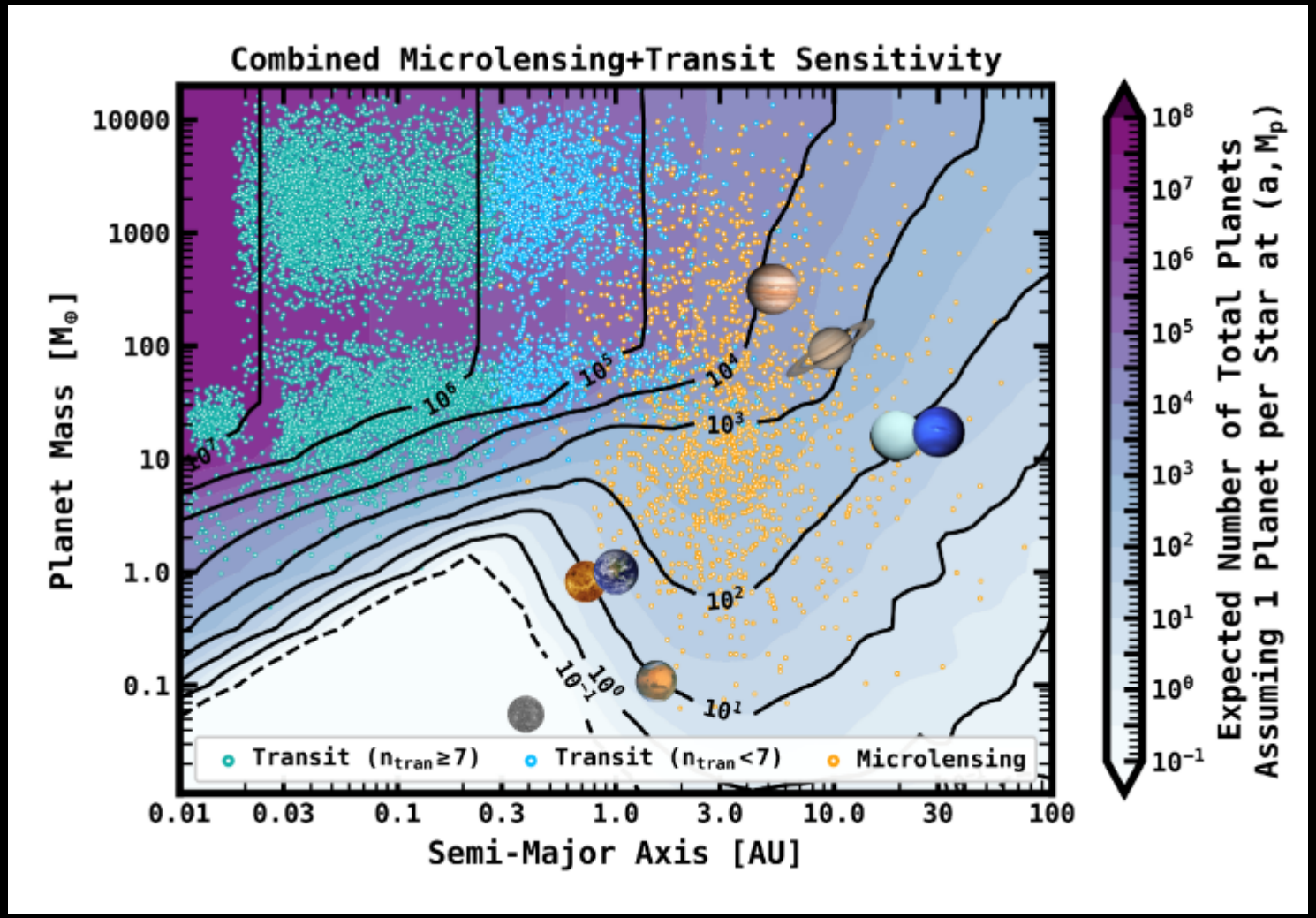


Wilson et al. 2023

Estimated Exoplanet Yield

- ~100k warm and hot planets
- ~1500 Bound Cold planets
- ~300 Free floating planets
- Sensitivity to planets in all major Galactic stellar populations



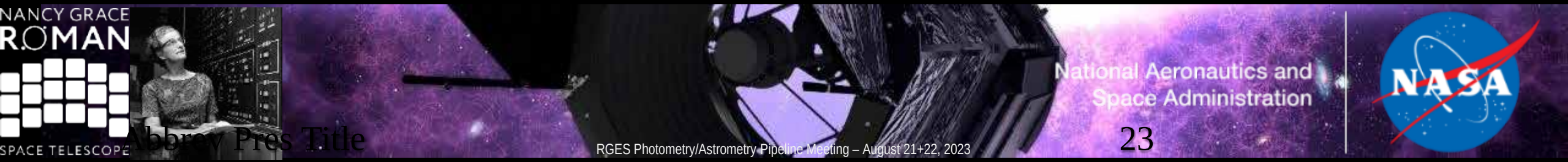


Wilson et al. 2023

D.14 Nancy Grace Roman Space Telescope Research and Support Participation Opportunities

"This program element solicits proposals to work on preparation for the operational phase of the Nancy Grace Roman Space Telescope, using one of three categories depending on the type of work being proposed."

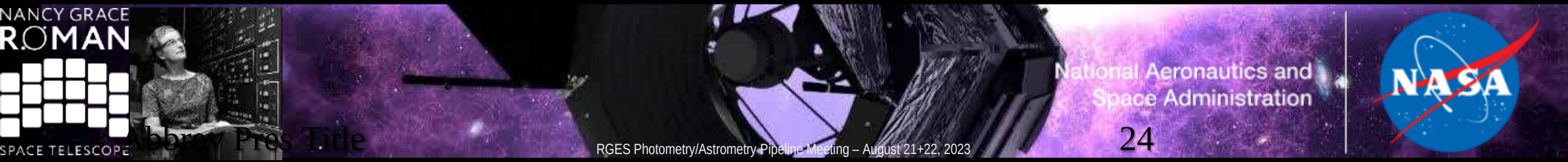
- Wide Field Science (WFS)
  - "Supports investigations that prepare for and/or enhance the science return of Roman that can be addressed with its WFI"
- WFI Project Infrastructure Teams (PIT)
  - "Sustained funding for teams to work in partnership with the Science Centers to develop scientific infrastructure needed to enable the community to pursue Roman's ambitious science goals."
- Coronagraph Community Participation Program (CPP)
  - "Solicits individuals or very small teams to work with the Coronagraph Instrument team to plan and execute its technology demonstration observations… will join to form the single team that plans and executes Coronagraph Instrument technology demonstration observations.



Selected proposals

30 proposals selected (5 PIT, 18 WFI, 7 CPP)

- Two exoplanet/related PIT proposals
  - Roman Galactic Exoplanet Survey (RGES) PIT – Scott Gaudi PI, Dave Bennett and Keivan Stassun Co-PIs
  - RAPID: Roman Alerts Promptly from Image Differencing - Mansi Kasliwal PI
- Two exoplanet/related WFI proposals
  - Rubin Increases the Power of Roman - Rosanne Di Stefano PI
  - Laying the Foundation for a Comprehensive View of Transiting Exoplanets with GBTDS - Elisa Quintana PI
- 7 CPP proposals



RGES PIT Members

Scott Gaudi (Ohio State) – PI
David Bennett (GSFC) – Co-PI
Keivan Stassun (Vanderbilt) – Co-PI
Michael Albrow (Canterbury)
Stephan Alexander (Vanderbilt)
Marcus Alfred (Howard)
Jay Anderson (STScI)
Etienne Bachelet (IPAC)
Jean-Philippe Beaulieu (IAP)
Andrea Bellini (STScI)
Chas Beichman (JPL)
Aparna Bhattacharya (GSFC)
Ian Bond (Massey)
Valerio Bozza (Salerno)
Christopher Brandon (OSU)
Sebastiano Calchi Novati (IPAC)
Sean Carey (IPAC)
Jessie Christiansen (NExScI)
Andrew Cole (Tasmania)
Jason Eastman (Harvard)
Macy Huston (Berkeley)
Markus Hundertmark (Heidelberg)
Stela Ishitani Silva (GSFC)
Samson Johnson (JPL)
Sinclaire Jones (OSU)
Naoki Koshimoto
Casey Lam (Carnegie)
Jessica Lu (Berkeley)
David Nataf (Johns Hopkins)
Shota Miyazaki (JAXA)
Shude Mao (Tsinghua)
Przemyslaw Mróz (Warsaw)
Greg Olmschenk (GSFC)
Matthew Penny (LSU)
Radek Poleski (Warsaw)
Clement Ranc (IAP)
Rachel Street (LCO)
Takahiro Sumi (Osaka)
Daisuke Suzuki (Osaka)
Sean Terry (GSFC)
Yiannis Tsapras (Heidelberg)
Aikaterini Vandorou (GSFC)
Joachim Wambsganss (Heidelberg)
Jennifer Yee (SAO)
Weicheng Zang (CfA)
Keming Zhang (UCSD)
Neil Zimmerman (GSFC)
Farzaneh Zohrabi (LSU)

… and more on the way …

Roman Galactic Exoplanet Survey Project Infrastructure Team (RGES PIT) Goals

- Developing sophisticated end-to-end (“pixels to occurrence rates”) survey simulations
  - Used for estimating the science yield and optimizing the survey strategy
  - Used to make end-to-end tests of the data reduction and analysis pipelines
- Use these to help define the survey strategy for the RGBTDS and RGPS
  - Must consider the full range of science (not just exoplanets) enabled by the GBTDS
  - What metrics should be used to optimize the survey strategy?
- Develop crowded field photometry and astrometry pipelines in collaboration with the Roman Science Support Center (SSC)
  - Must been the project requirements, but also want to…
  - “Dig into the dirt” to reach the photon noise limit
- Develop Human Infrastructure to grow the Roman microlensing user community

Human Infrastructure Development

- Led by Co-PI Keivan Stassun
- Goal: To expand the scientific capacity and impact of the US microlensing community while simultaneously increasing its inclusiveness, diversity, equity, and accessibility, and to develop outreach and citizen science activities that provide entryways for the public to engage with the RGES science and the RST mission.
- Training of undergraduate and graduate students and postdoctoral researchers
  - 2025 Sagan Summer Workshop will be on microlensing with Roman
- Outreach and Citizen Science

This is an exciting time!

- Roman continues to stay on schedule and under budget with launch currently anticipated in late 2026
- That's less than THREE YEARS FROM NOW! 😳
- There's a lot that needs to be done before launch, during the prime mission, and after the prime survey is complete.
- **The RGES PIT needs your help!**
- For those of us who have been in the field for a long time, Roman represents the culmination and reward of many years of effort and sacrifice!
- For those of you who are new to microlensing, Roman represents a fantastic opportunity.