Galactic Bulge Time Domain Survey Definition Committee Report

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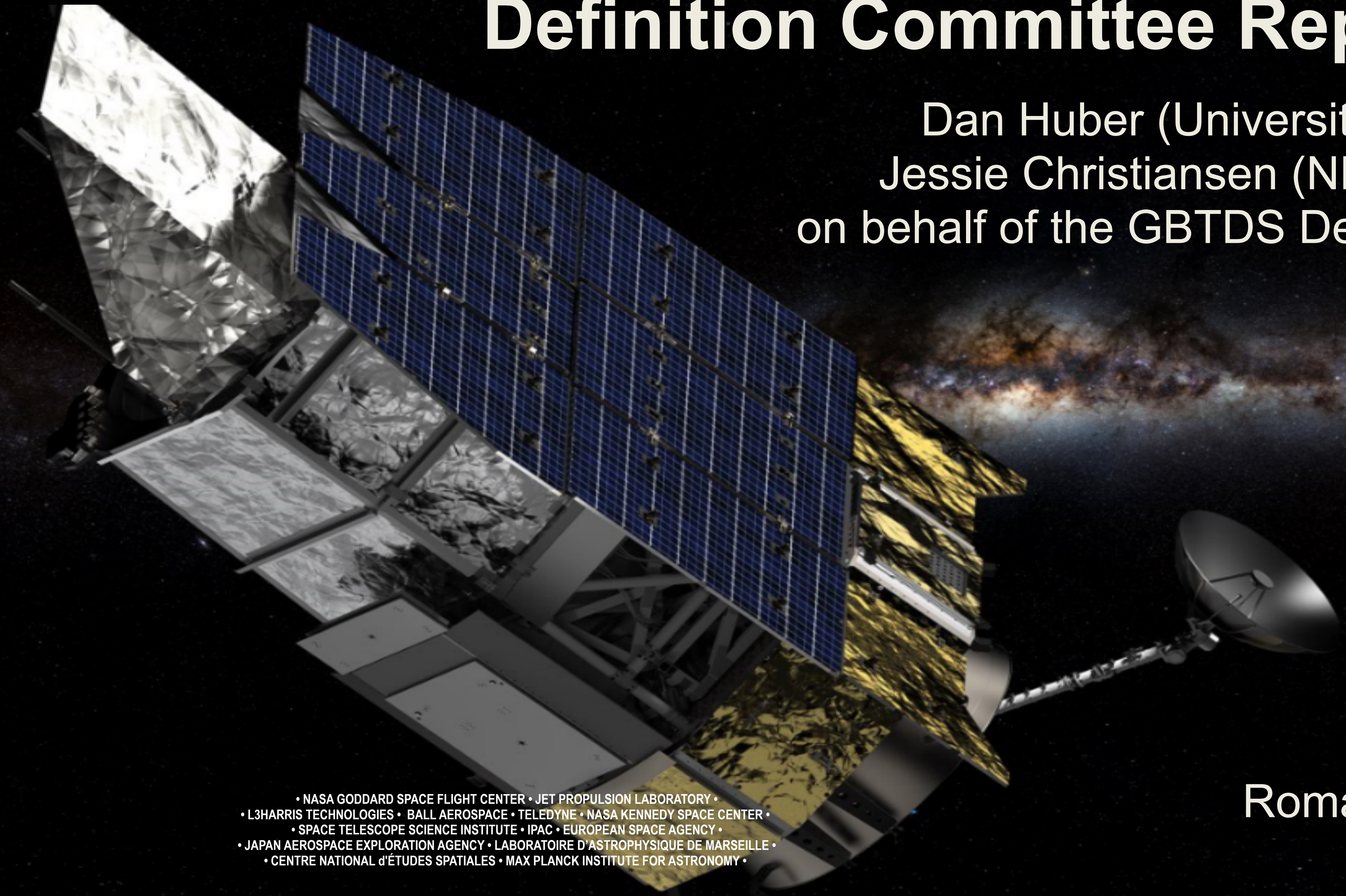
Jessie Christiansen (NExScI/Caltech)
on behalf of the GBTDS Definition Committee



Roman Community Forum
January 2025

GBTDS Definition Committee Members

Jessie Christiansen (NExScI/Caltech, Co-chair)

Dan Huber (UH/USyd, Co-chair)

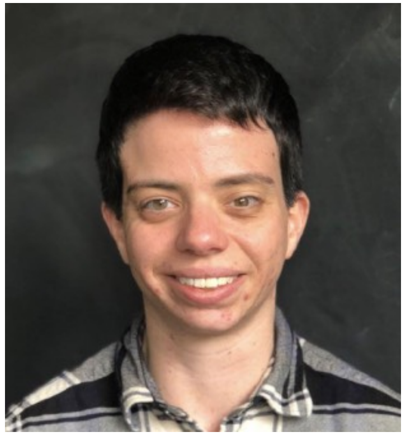
Annalisa Calamida (STScI)

Jennifer Sobeck (IPAC)

Matthew Penny (LSU), PIT Liasion

Ben Montet (UNSW)

Hans-Walter Rix (MPIA)



Kris Pardo (USC)

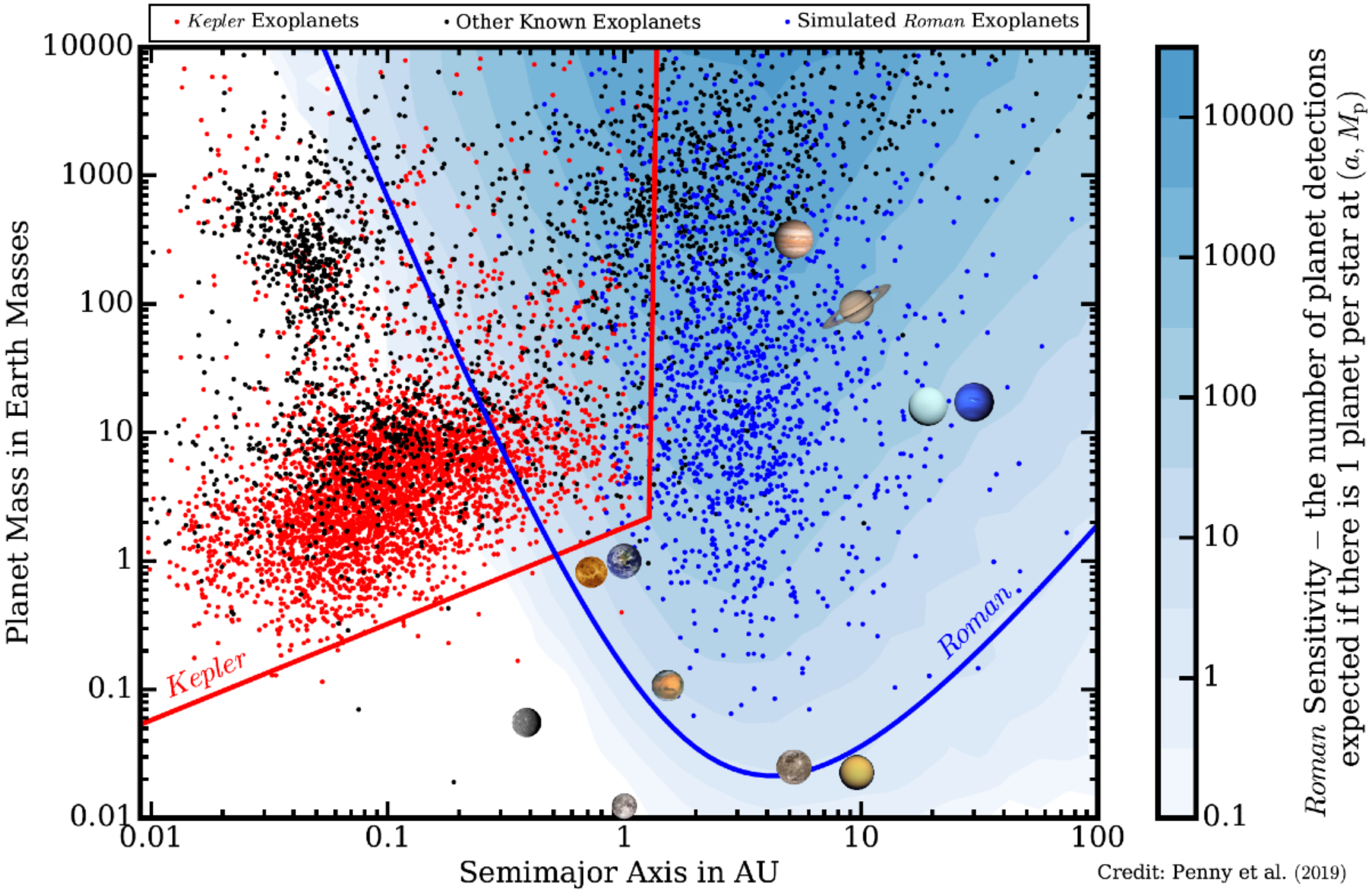
Jessica Lu (Berkeley)

Eduardo Martin (ESO)

Solar system liaisons: Susan Benecchi (PSI) & Rosemary Pike (CfA); **Additional contributors:** Macy Huston (UCB), Natasha Abrams (UCB), Jonas Klüter (LSU), Farzaneh Zohrabi (LSU), Alison Crisp (OSU), Trevor Weiss (CSULB), Noah Downing (OSU)

Roman GBTDS: Science Requirements

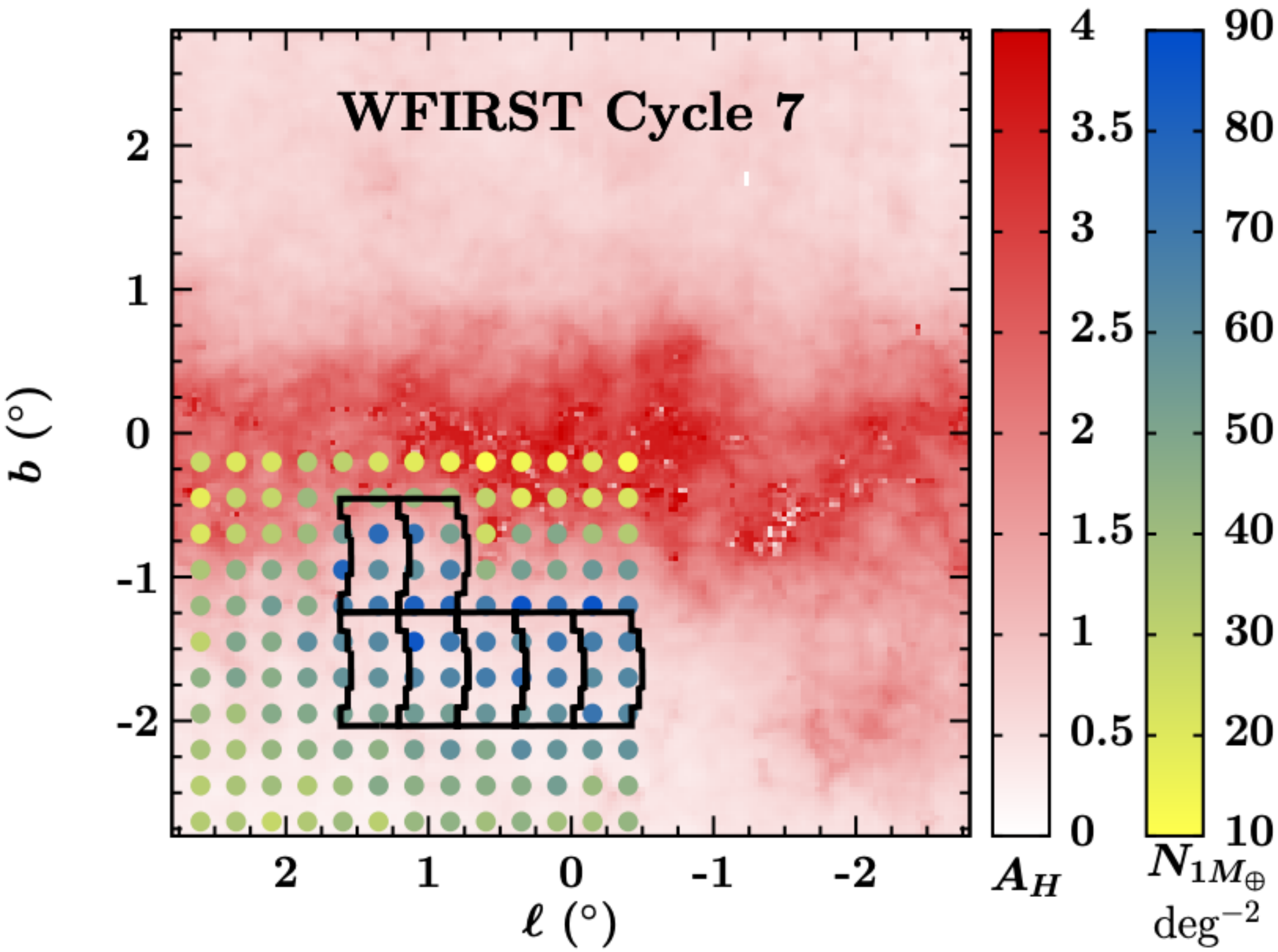
Roman will carry out a statistical census of exoplanetary systems in the Galaxy, from the outer habitable zone to free floating planets, including analogs to all of the planets in our Solar System with the mass of Mars or greater, by monitoring stars toward the Galactic bulge using the microlensing technique.



Credit: Penny et al. (2019) ApJS 241, 3

Penny+ 2019

Roman GBTDS: Reference Survey



Penny+ 2019

Penny+ 2019 reference:

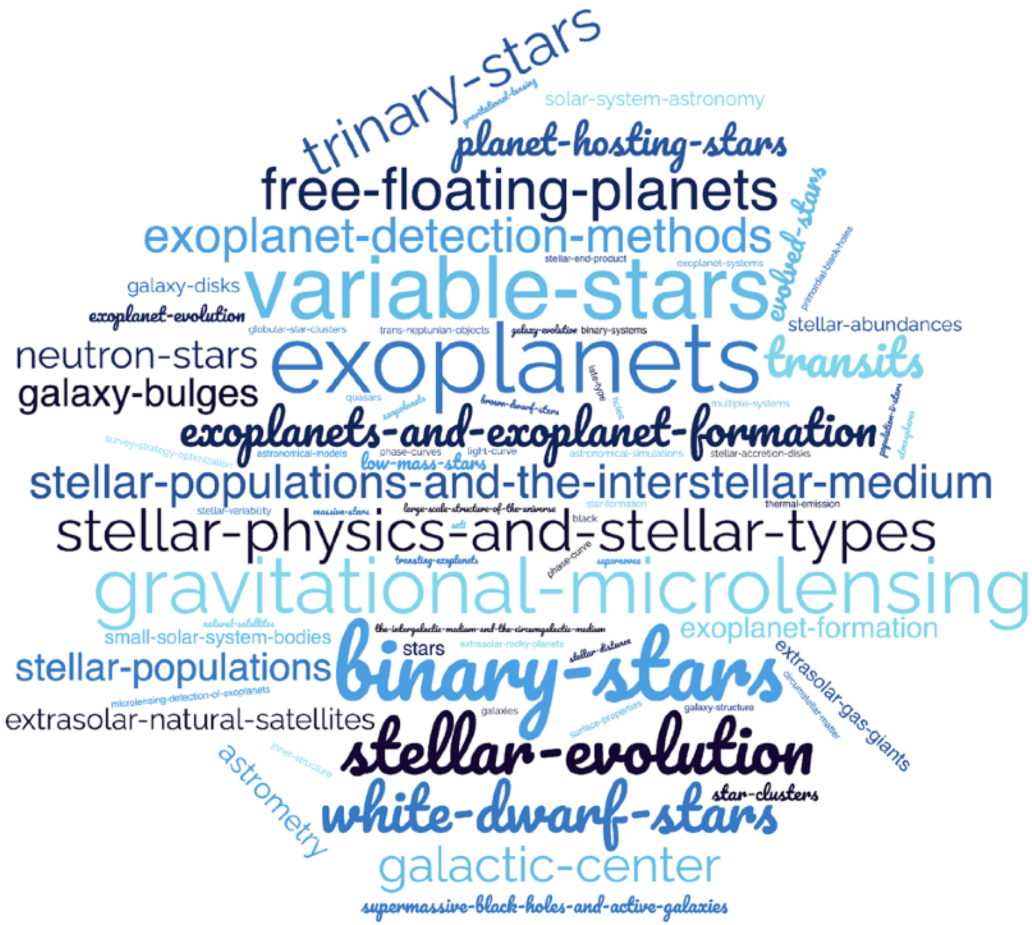
- 420 day *survey*
- 6 x 72 day observing *seasons*
- 7 *fields* observed in each season (~2 deg² survey area)
- 15 minute cadence with broad filter
- 12 hour cadence with narrow filter

Survey changes considered:

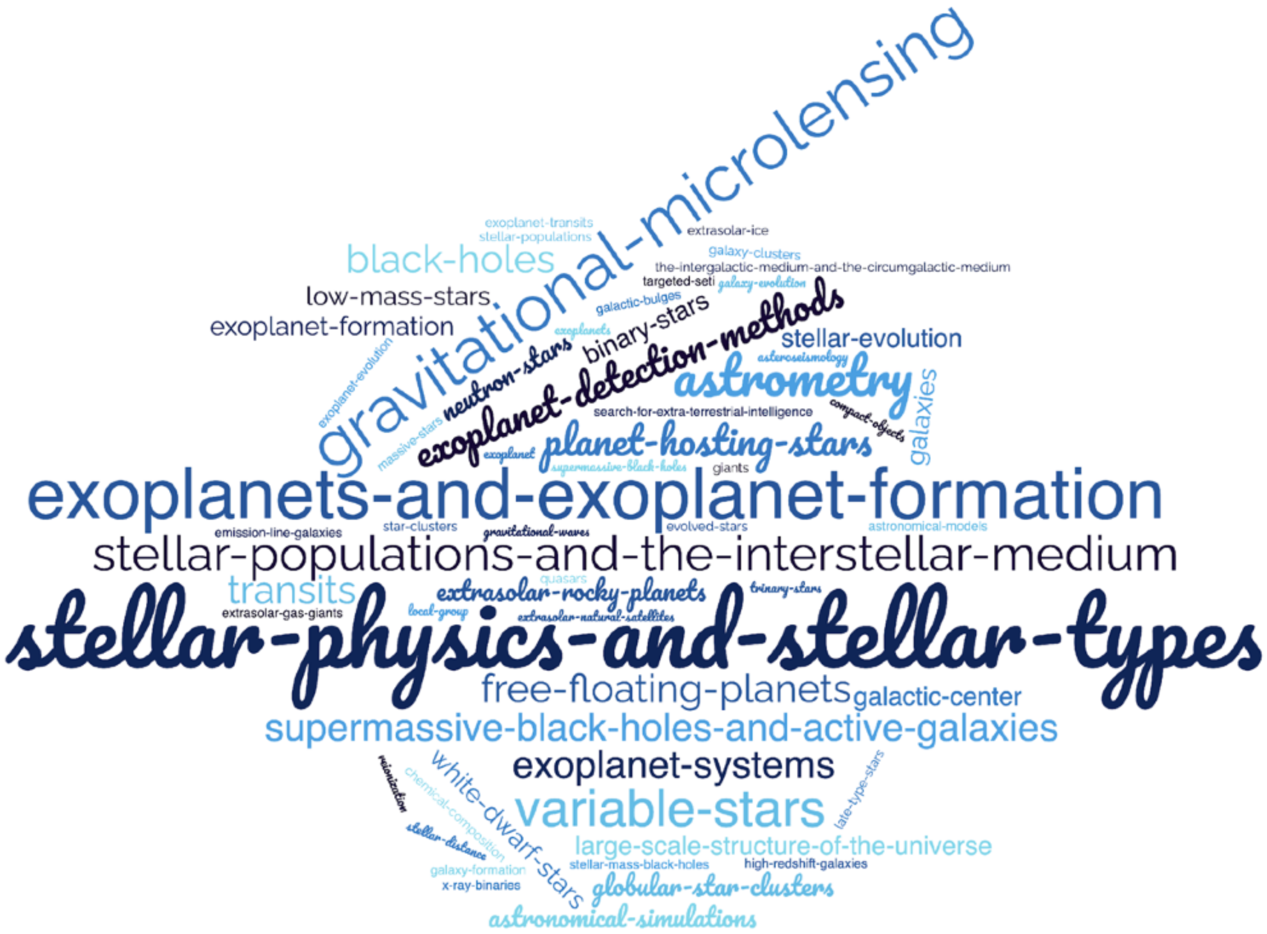
- 380-440 day *survey*
- 60-72 day observing *seasons*
- 5-9 *fields* observed in each season
- 7-15 minute cadence with broad filter
- 3-12 hour cadence with narrow filter(s)

Roman GBTDS: Community Input

23 White papers



43 Science Pitches



Follow-up call for updates sent to white paper authors in March 2024

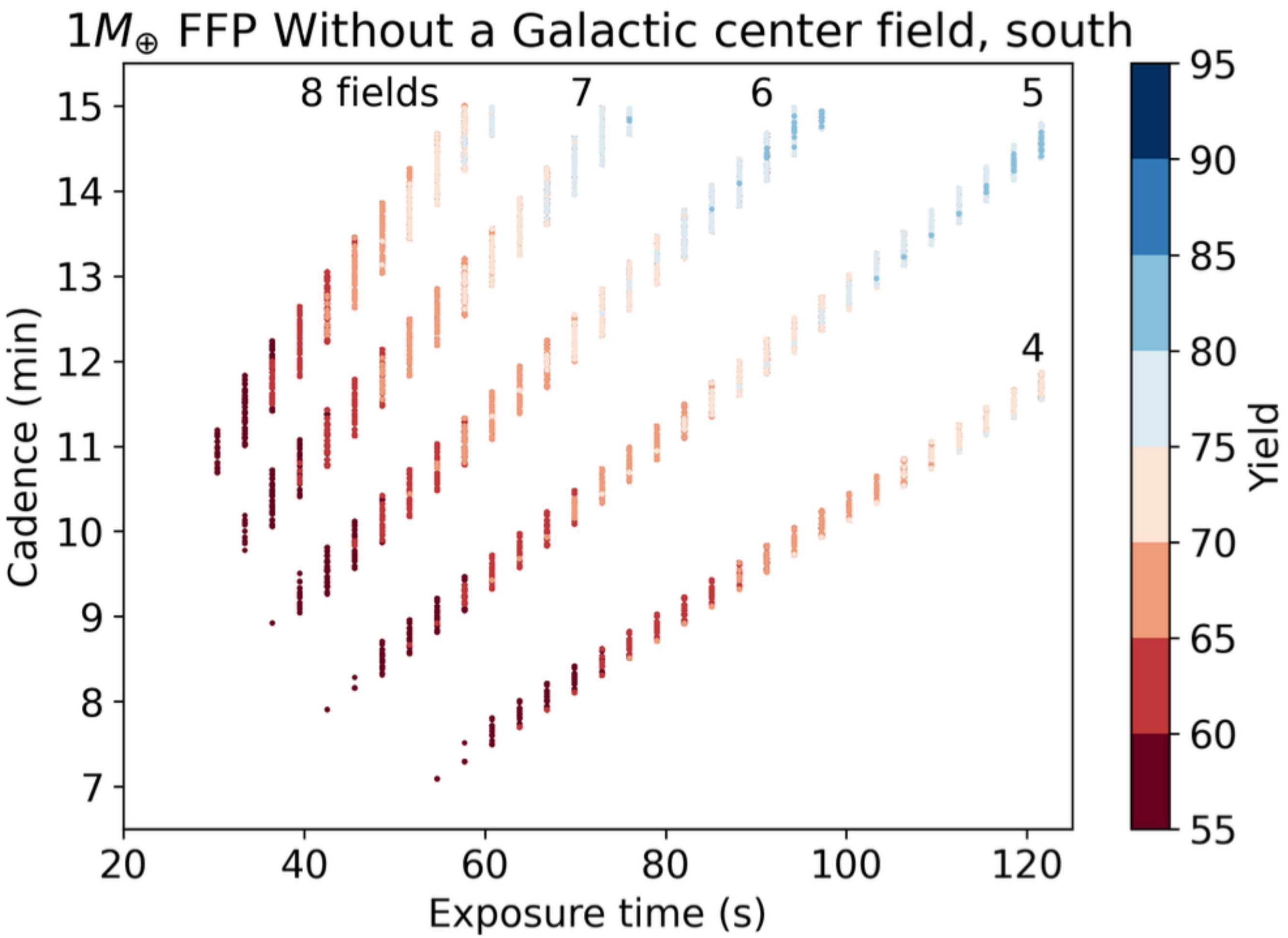
Review Metrics

Score		Impact	Feasibility	Synergy: Science	Synergy: Surveys	Uniqueness
		How impactful would the science goal be if achieved, over how wide an area of astrophysics?	*Given what we (the committee) know about the improvement in the Roman survey parameters, and knowing that we are planning to perform more detailed simulations of the highest rated science programs, how likely is the proposed strategy to yield the stated science result?*	*IF there is a proposed change to the survey, how useful would the proposed survey strategy (e.g. faster cadence, additional fields, different filters) be for other science areas?*	*IF there is a proposed change to the survey, how useful would the proposed survey strategy (e.g. faster cadence, additional fields, different filters) be for other surveys, including ground-based surveys and space-based missions?*	*How uniquely is the Roman GBTDS suited to address this science?*
3	Good	The proposed science would have significant impact, resolving long-standing questions, opening up new areas of inquiry, and/or impacting multiple sub-fields in astronomy.	The proposed strategy is very likely executable, given the improved survey parameters, while achieving the GBTDS Level 1 science requirements.	The proposed strategy would enable or enhance science return for a number of science areas, as explicated in other white papers and science pitches.	The proposed strategy would enable or enhance science return for a number of other surveys/missions, as explicated in other white papers and science pitches.	The Roman GBTDS would be the only opportunity in the next ~decade to perform this survey and address the stated science case, and there are no other data with which this science could be enabled.
2	Average	The proposed science would have some impact, addressing specific focused questions, extending previous datasets usefully, and/or impacting one sub-field in astronomy.	The proposed strategy is potentially executable, given the improved survey parameters, while achieving the GBTDS Level 1 science requirements.	The proposed strategy may enable or enhance science return for a limited number of science areas.	The proposed strategy may enable or enhance science return for a limited number of other surveys/missions.	The Roman GBTDS would be one of limited opportunities to address the stated science case.
1	Poor	The proposed science would have minimal impact, not addressing any particular stated questions, and repeating or only marginally extending previous work.	The proposed strategy is sufficiently far from the nominally stated parameters that, even with improved survey parameters, it is unlikely that we would be able to perform the proposed survey and achieve the Level 1 GBTDS science requirements.	The proposed strategy would not enable or enhance science return for other science areas.	The proposed strategy would not enable or enhance science return for other surveys/missions.	The stated science case could be addressed with other upcoming opportunities and/or could already be addressed with archival data.

Committee reviewed & ranked white papers and science pitches over 4 week period, followed by identification and prioritization of common science themes. Community interactions during Roman in-person meeting (Pasadena, July 2024), online community forum (July 2024) and online town hall meeting (August 2024)

Trade Spaces & Science Requirements

- Key trade space: exposure time, number of fields, cadence (requirement < 15 mins)
- Updated simulations use latest gal. model, slew & settle times (Appendix A; lead: Matt Penny)
- Simulations produce exoplanet yields (based on fiducial mass function by Cassan+ 2012) & optimized field layouts
- Committee considered & voted on scenarios produced by simulations

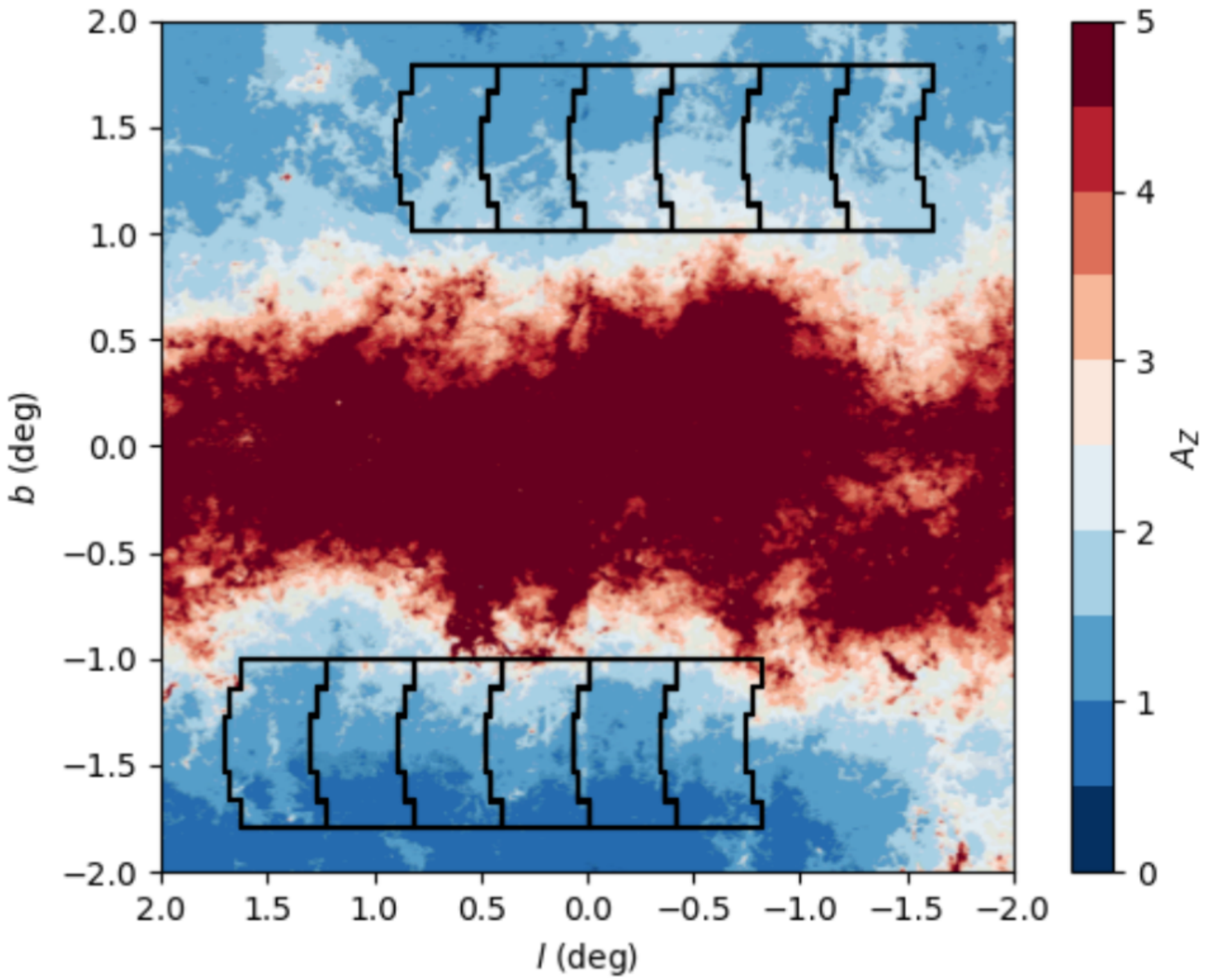


GBTDS Definition Report Fig. 22

Recommendation 1: High-Cadence Field Parameters

- First three and last three bulge seasons should be observed at high cadence (<15 mins) to maximize the number of microlensing events for which source-lens proper motion measurements are possible

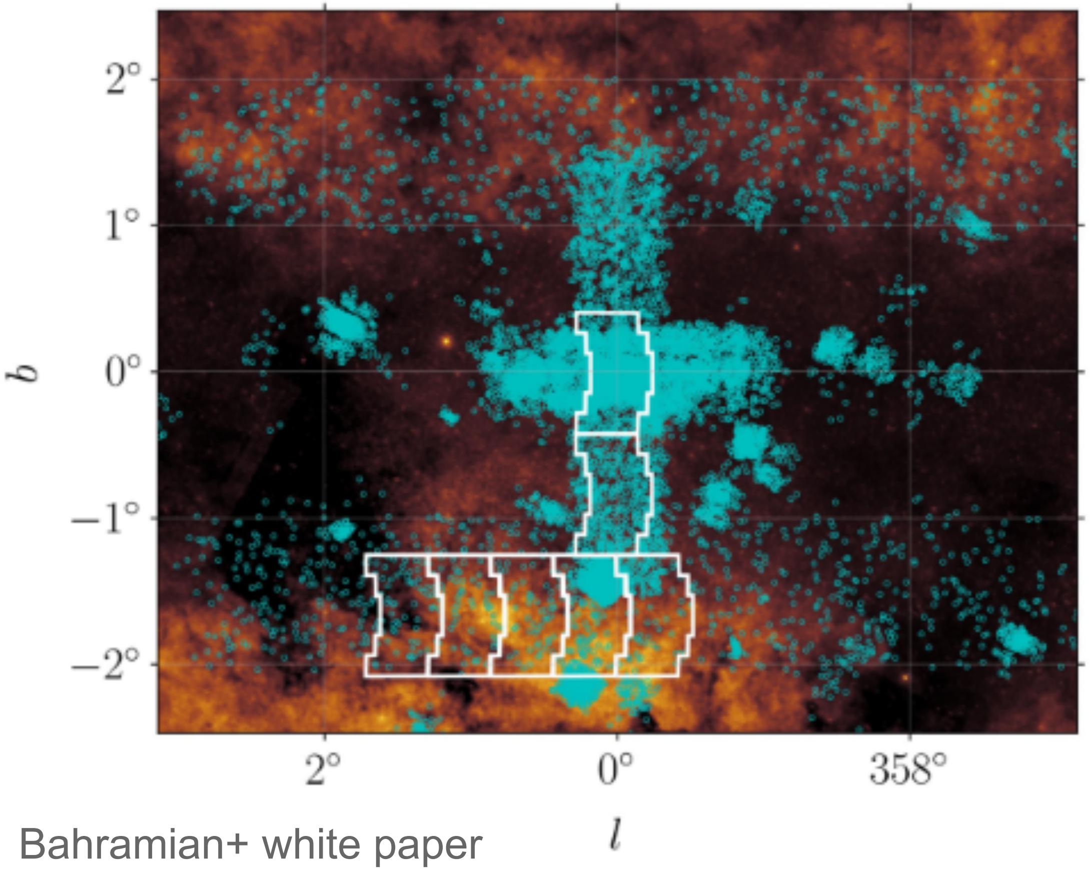
- Fields should be placed in the southern galactic bulge to enable blue filter observations (less extinction) and due to longer history of ground-based observations



GBTDS Definition Report Fig. 6

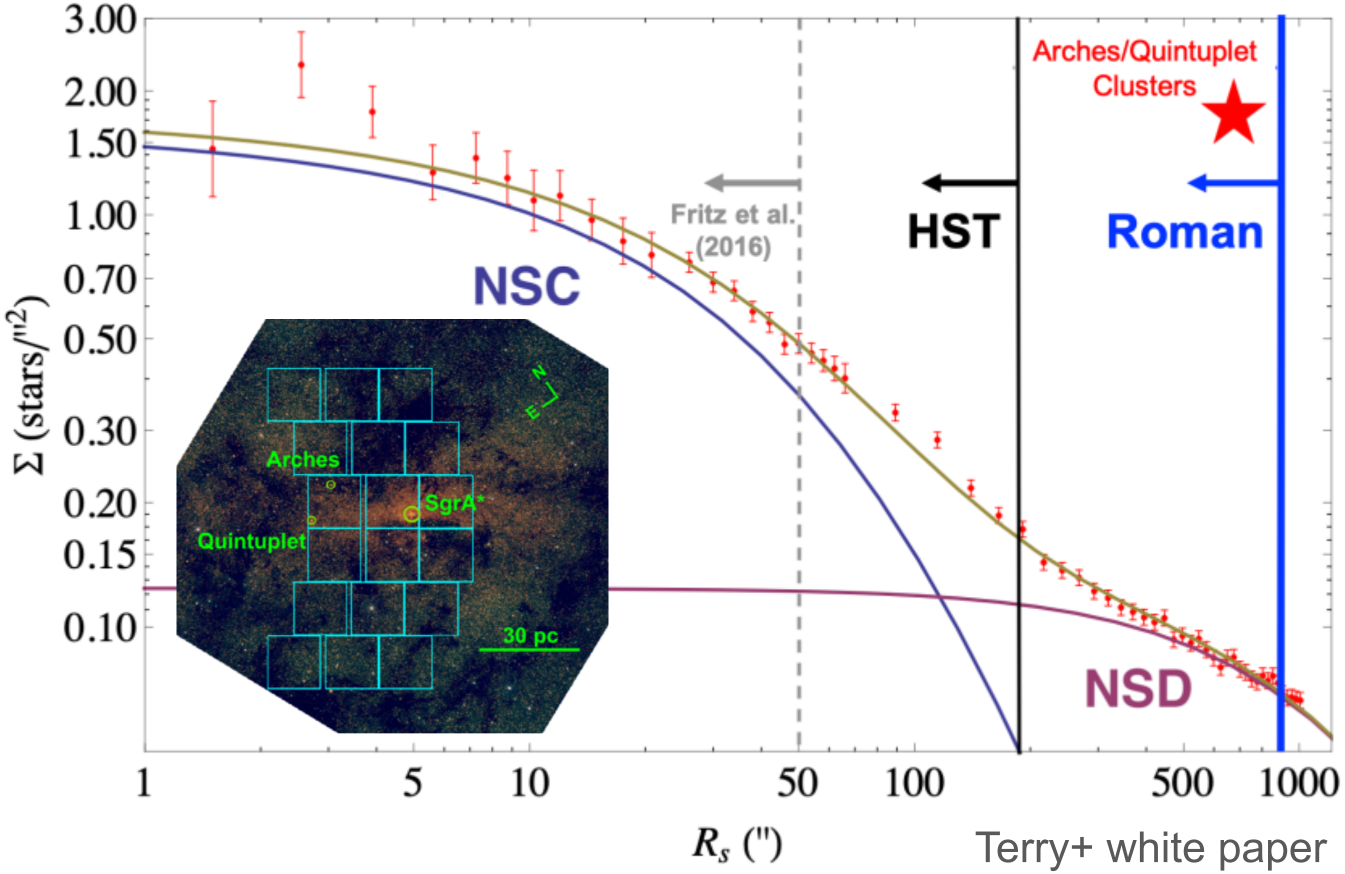
Recommendation 2: Add Galactic Center Field

Increase overlap with Chandra X-ray sources



Bahramian+ white paper

Probe stellar populations in the galactic center

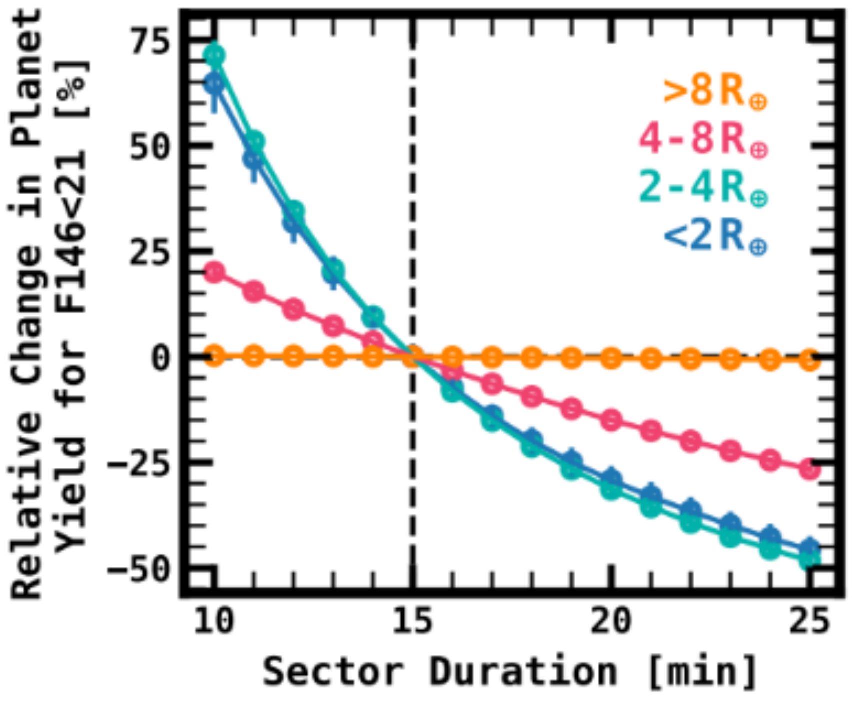


Terry+ white paper

Science: compact object binaries, variable stars, transiting exoplanets, SgrA* accretion, …

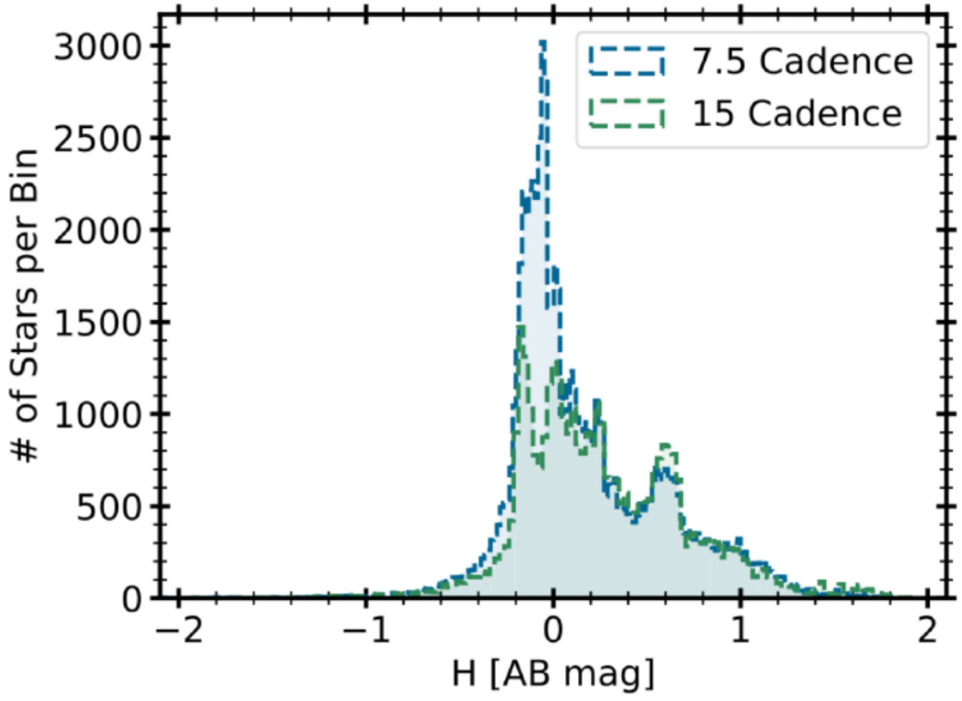
Recommendation 3: Maximize Season Duration & Cadence

Transiting Exoplanets



Wilson+ white paper

Asteroseismology of Red Giants

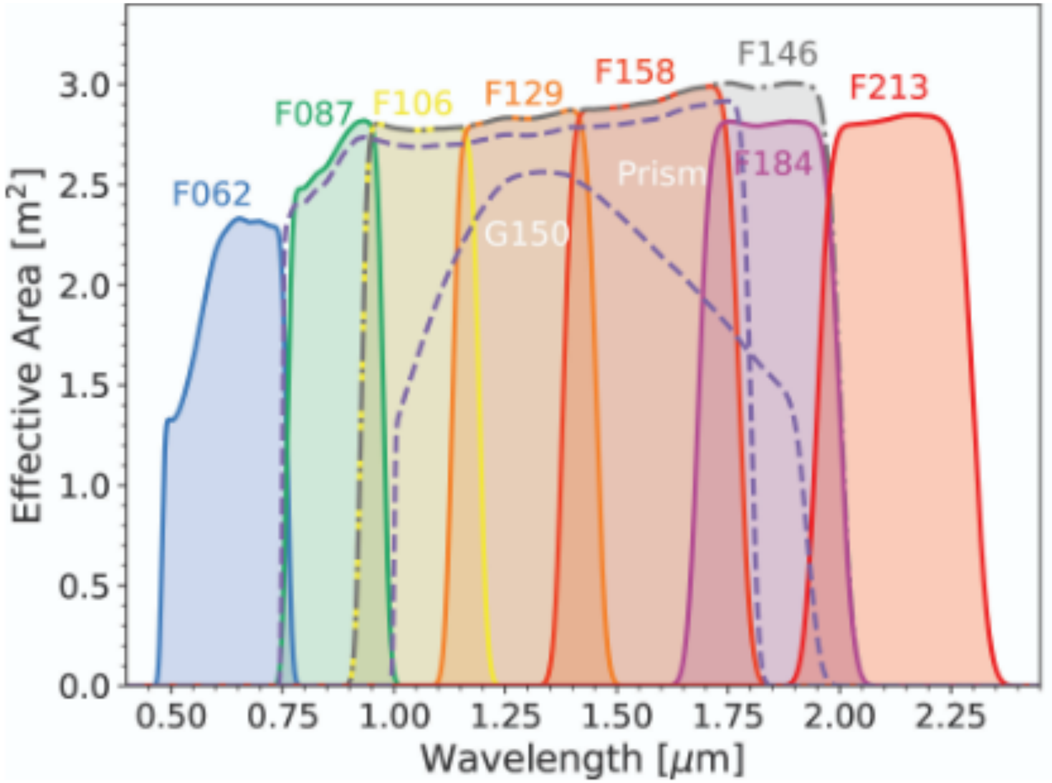


Weiss, Downing+ in prep

Also strong benefits for exoplanet microlensing: fast cadence improves detection of <~ Mars mass free-floating planets (Gould white paper), maximum duration enables more exoplanet microlensing mass measurements (Penny white paper)

Recommendation 4: Maximize Color Cadence

- Requirement of 1 blue filter (< 1 μm) and 1 red filter (> 1 μm) at better than daily cadence to support exoplanet microlensing mass measurements
- Recommend two filter cadences with 6 hours spaced by 3 hours (i.e. one additional filter every three hours)
- Recommended filter choices are F087 (~ Sloan z) and F213 (~2MASS K), to be confirmed by PIT and WFS teams

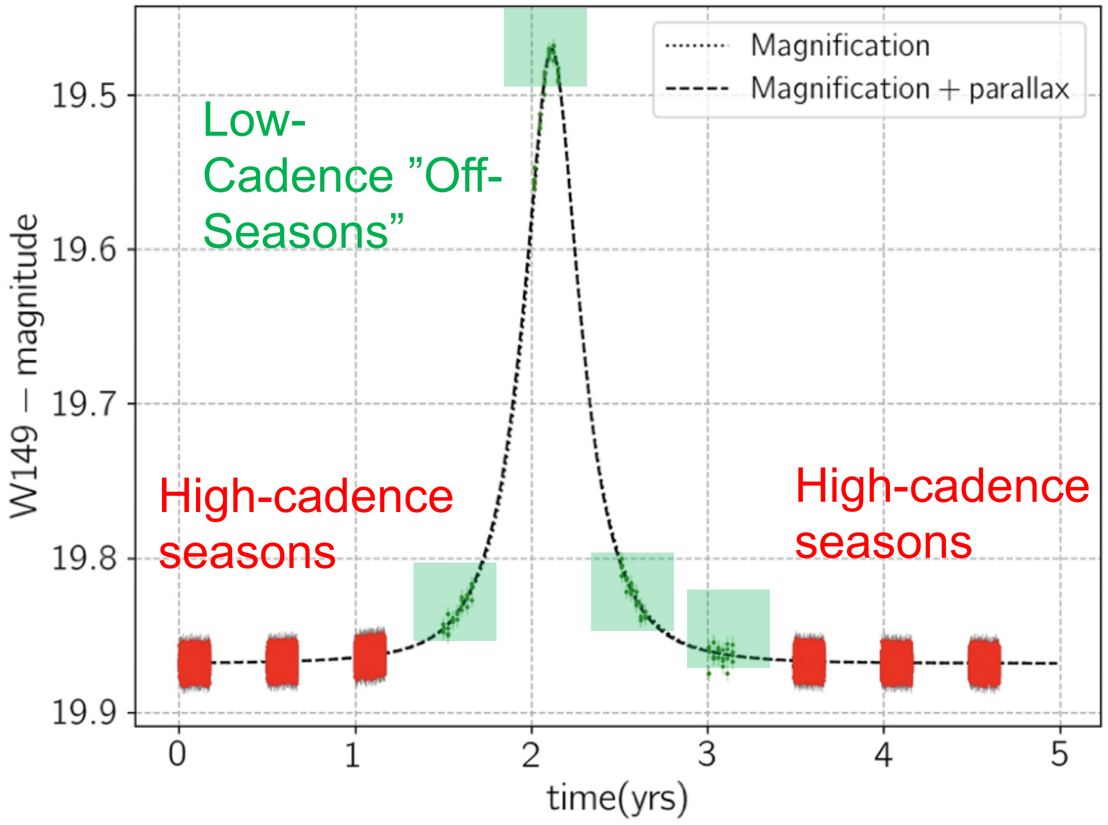


Mass	N	f_{FS}	f_{color}			N_{3hr}/N
	(12hr)	(12hr)	(12hr)	(6hr)	(3hr)	(3hr)
$0.1M_{\oplus}$	187^{+2344}_{-187}	100%	11%	35%	56%	95%
$1M_{\oplus}$	273^{+455}_{-222}	70%	12%	23%	37%	97%
N_{filter}	–	–	1,728	3,456	6,912	–

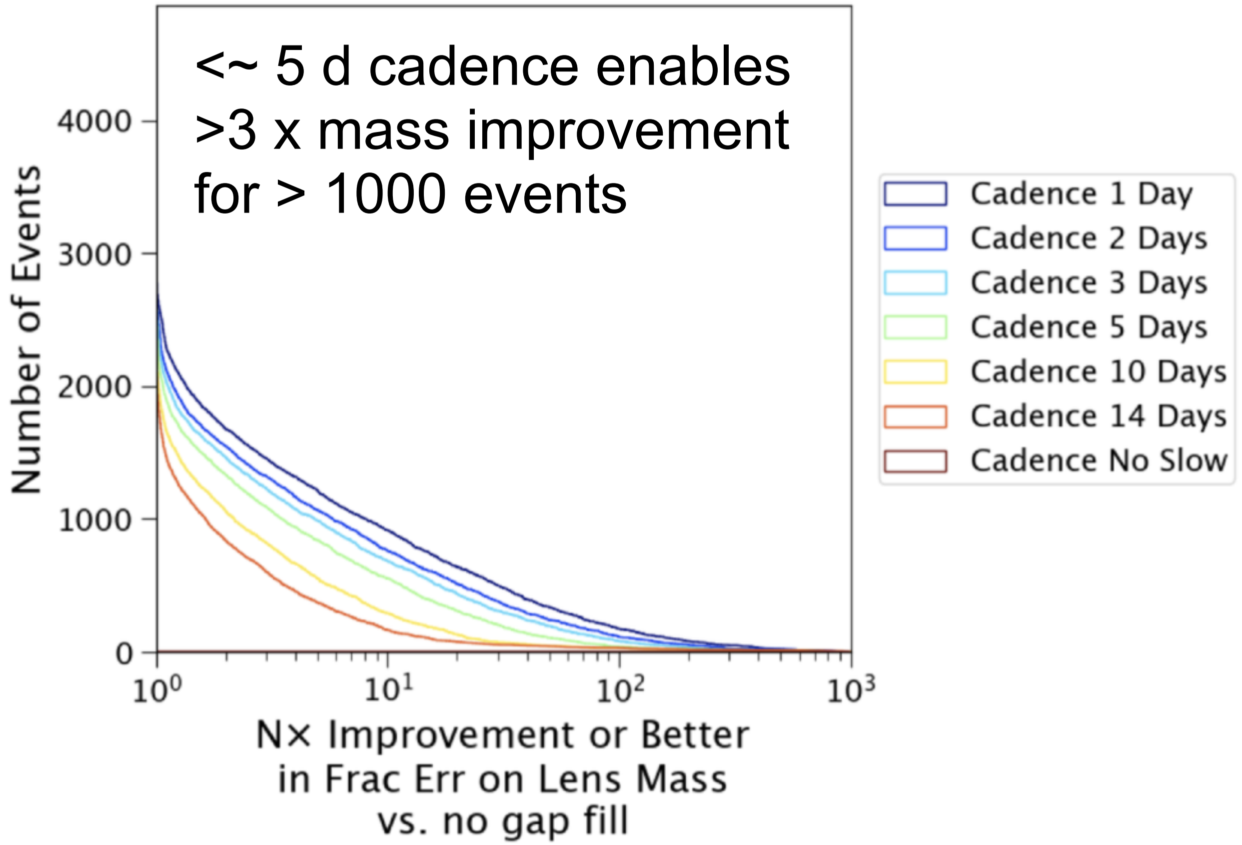
Sumi+ white paper

Recommendation 5: Add Low-Cadence Seasons

Low cadence observations during “off-seasons” will enable well-sampled light curves and astrometry for isolated black-hole microlensing events

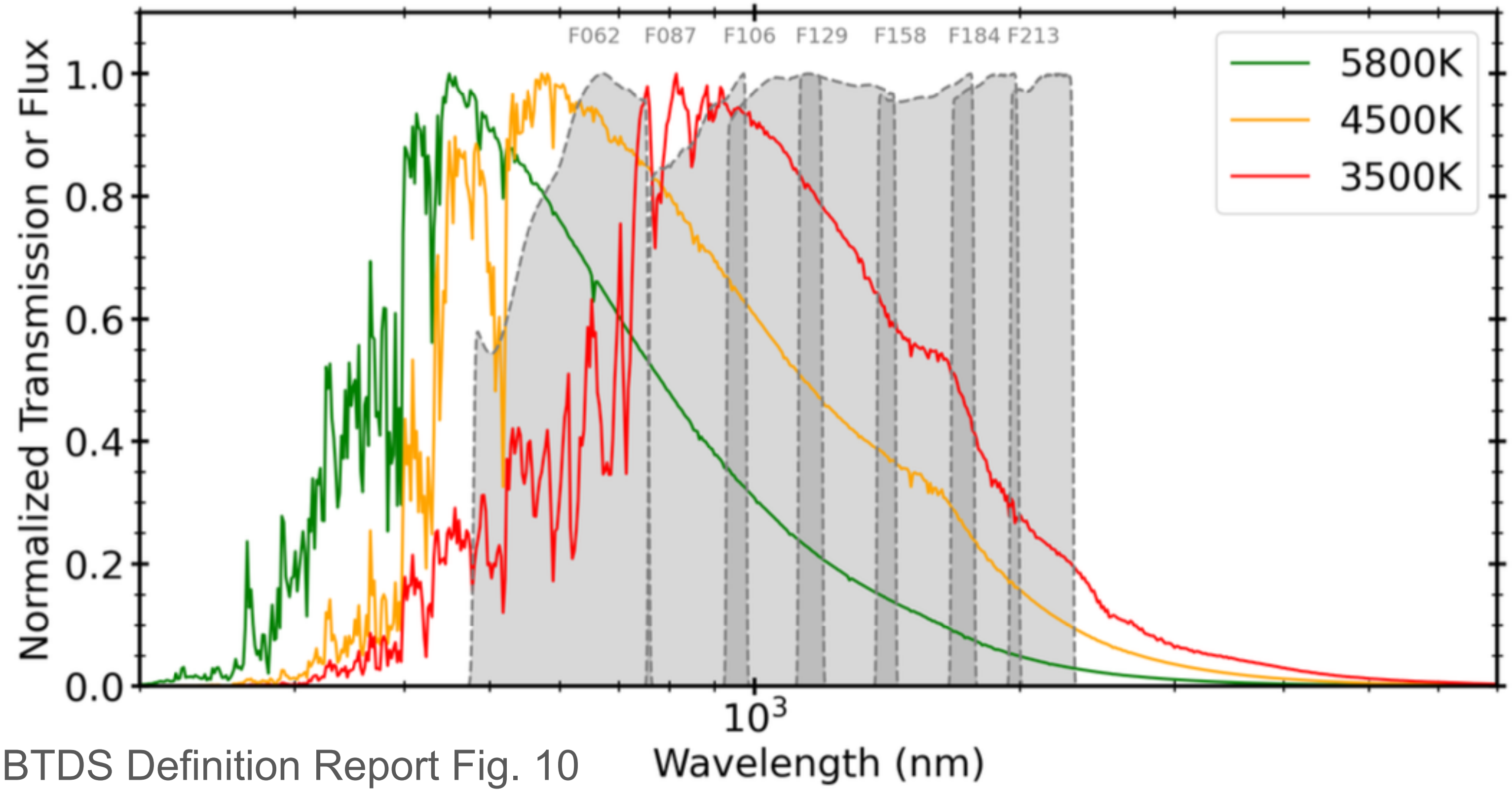


Sahu+ white paper



GBTDS Definition Report Fig. 9

Recommendation 6: Snapshot Photometry



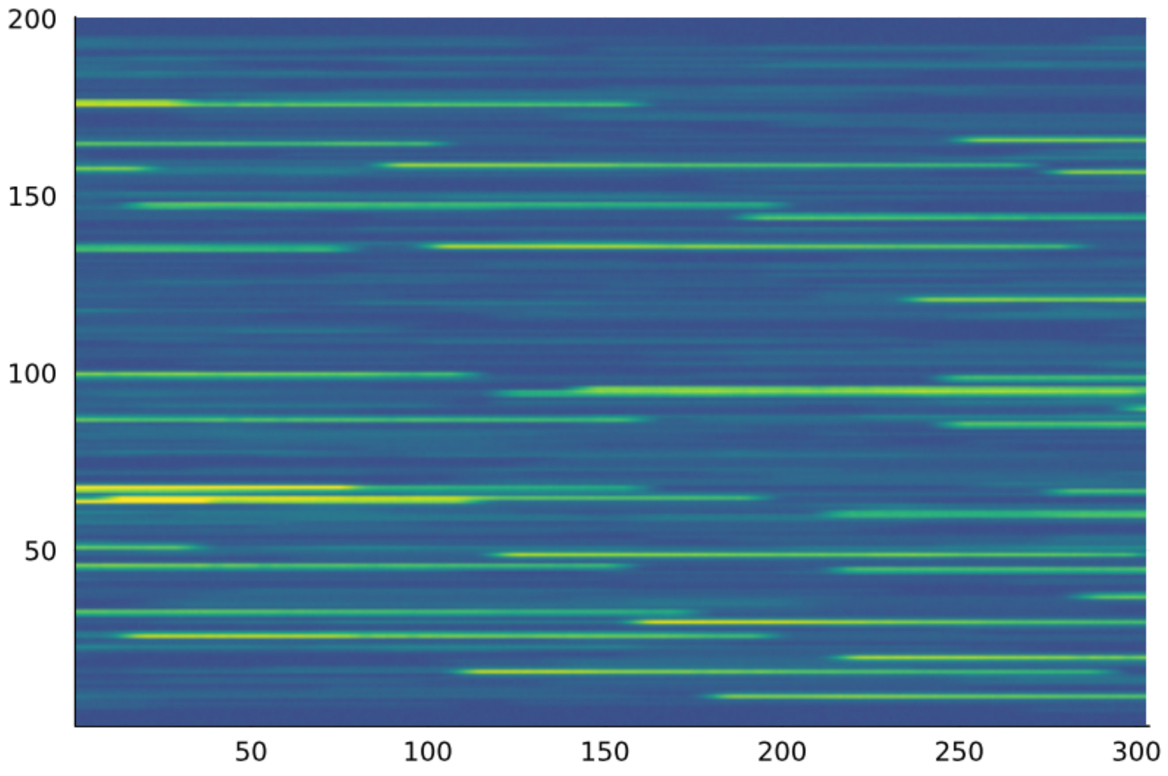
GBTDS Definition Report Fig. 10

SNR=100

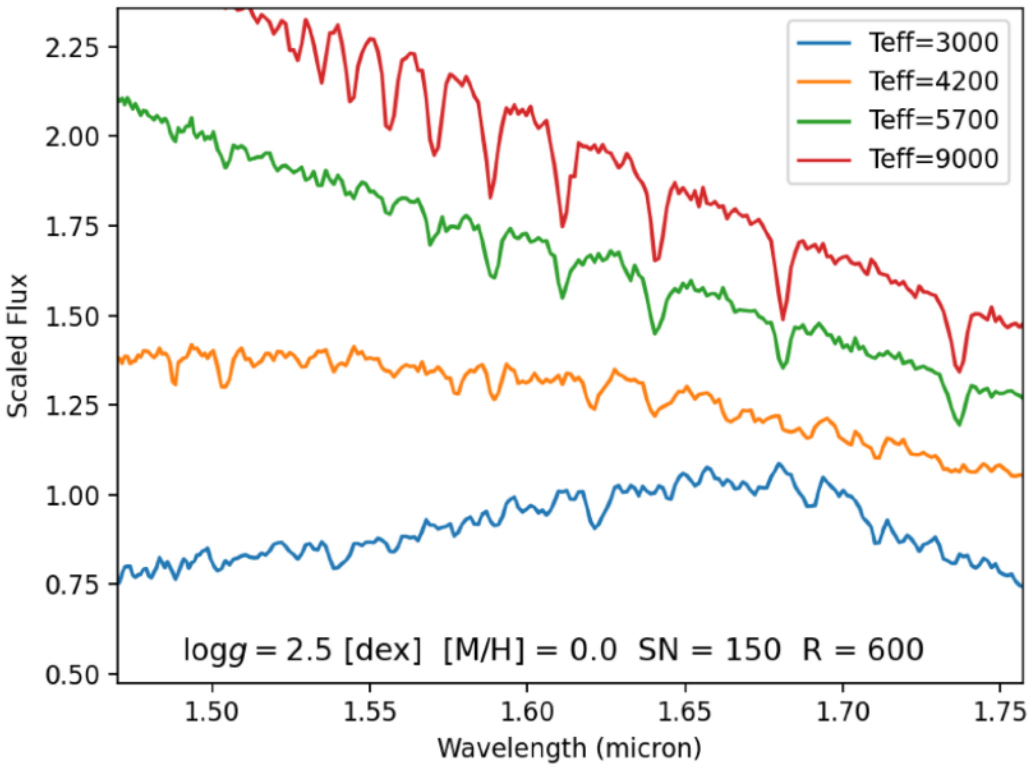
Filter	Exposure time (sec)
$F213$	286
$F184$	102.3 ←
$F158$	120.2 ←
$F129$	170.8 ←
$F106$	284.6 ←
$F087$	778
$F062$	4916 ←

Recommendation: observe all fields using the five science filters that are not obtained at higher cadence with SNR ~> 100 (except F062) for stellar characterization; ~5 hours per snapshot

Recommendation 7: Snapshot Spectroscopy



GBTDS Definition Report Fig. 11



GBTDS Definition Report Fig. 12

Recommendation: observe all fields using grism for detailed stellar characterization (temperatures, metallicities) and radial velocities for luminous stars. 1500 sec exposures to reach SNR=100 at K~16 (~3 hrs per snapshot)

Strategies Not Recommended

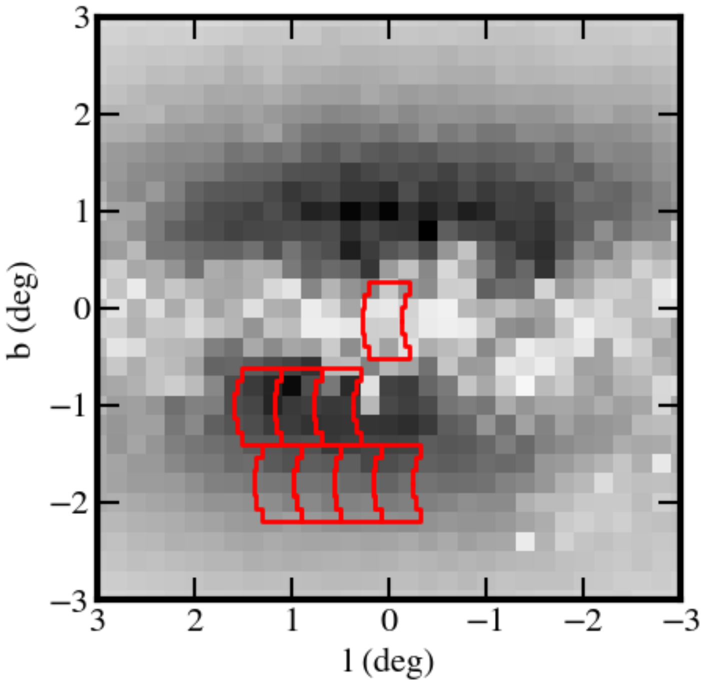
- **Add field covering a globular cluster:** high science value but considerable slew time, other clusters may provide better match to Roman FOV
- **Add field to observe Earth Transit Zone:** high science value but slew time prohibitively expensive
- **Very high-cadence (~1 min) observations:** high risk (GW detection) and limited commitment (~1 day) would likely be less impactful

GBTDS Definition Report Fig. 14

ROMAN SPACE TELESCOPE

Recommended Roman GBTDS Surveys

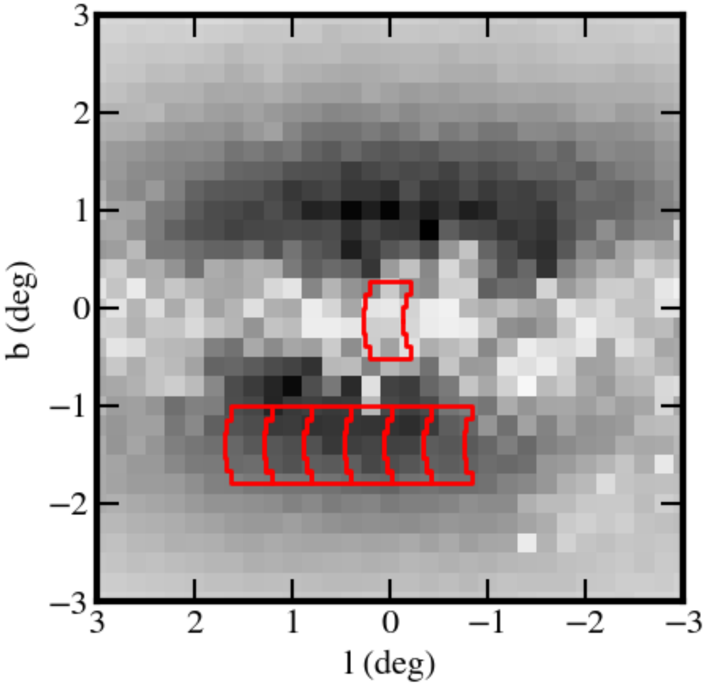
Underguide (380d)



- 6 x 63 day high cadence seasons
- 7 fields @ 12.6 min cadence
- Gal. Center @ 12-hour cadence
- No low-cadence seasons
- 2 phot. & grism snapshots

Minimal extra science to optimize meeting science requirements

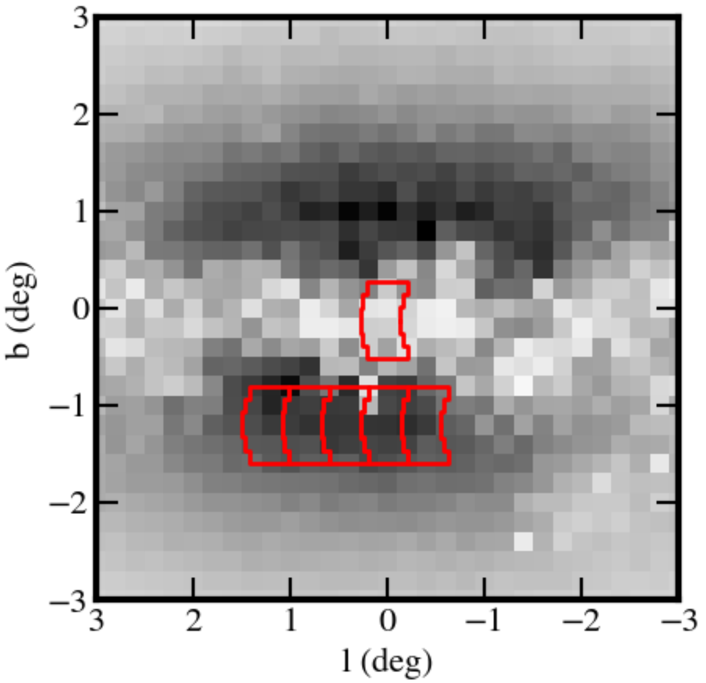
Nominal (420d)



- 6 x 68.5 day high cadence seasons
- 6 fields @ 14.8 min cadence
- Gal. Center @ 14.8 min cadence
- 4 low-cadence seasons @ 5 days
- 12 phot. & grism snapshots

Implements all science components while optimizing science requirements

Overguide (440d)



- 6 x 70.5 day high cadence seasons
- 5 fields @ 12.1 min cadence
- Gal. Center @ 12.1 min cadence
- 4 low-cadence seasons @ 3 days
- 30 phot. & grism snapshots

Maximizing extra science while optimizing science requirements

GBTDS Definition Report Fig. 15

Recommended Roman GBTDS Surveys

	420d	380d	440d
Survey Component	**Nominal**	Underguide	Overguide
Number of high-cadence seasons	6	6	6
Observing allocation per season (d)	68.5	63	70.5
Feasible season length (d)	72	72	72
Number of contiguous fields	6	7	5
Observing cadence (min)	14.8	12.6	12.1
Exposure time (sec)	73	57.8	66.9
Galactic center field cadence (min)	14.8	720	12.1
Number of low-cadence seasons	4	0	4
Observing cadence (days)	5	0	3
Number of photometry snapshots	12	2	30
Number of grism snapshots	12	2	30

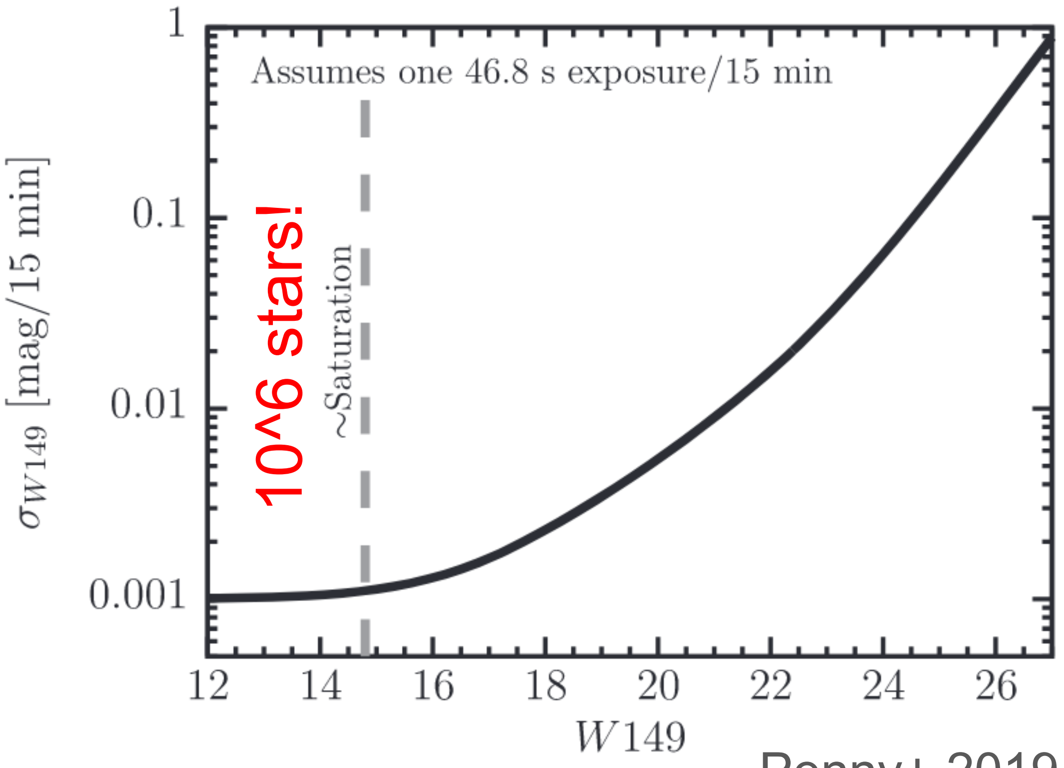
Constraints & Other Considerations

- **Scheduling:** first high-cadence season should occur as early as possible in the mission to extend photometric and astrometric baselines
- **Field Location:** <~ 0.2 degree shifts ok, but ensure that the galactic center field includes SgrA* and clusters (Arches, Quintuplet, NSC)
- **Start and end of science operations:** if commissioning ends during bulge season, start GBTDS if >8 days remain in the season. If mission is extended, push last bulge season as far back as possible.
- **Ancillary data:** not formally required but of high value, both for coordinated (e.g. Euclid, Rubin) and preparatory (e.g. HST, Subaru) observations.

Technical Checkpoints

- **Photometry:** Assuming MSOS will not produce light curves for saturated stars, project should engage the community, PIT, and WFS teams to perform early survey data analysis of saturated stars.

- **Spectroscopy:** Guiding performance in crowding fields is unknown, so recommend to engage with community about usefulness of data and magnitude limits



Penny+ 2019

- **Science requirements:** if PIT re-verification with early Roman data implies that science requirements are not met, allocate maximum duration for all high-cadence seasons