Roman/Subaru Synergistic Follow-up of RAPID-discovered transients

Updated 2025 March 25
(Strikeouts represent revisions of, plus new slides added to, December 2024 Roman/Subaru workshop presentation)

Schuyler Van Dyk, Mansi Kasliwal, and the RAPID team (Caltech, USA)

RAPID

Public Alert Stream
including all types of transients,
variables and moving objects

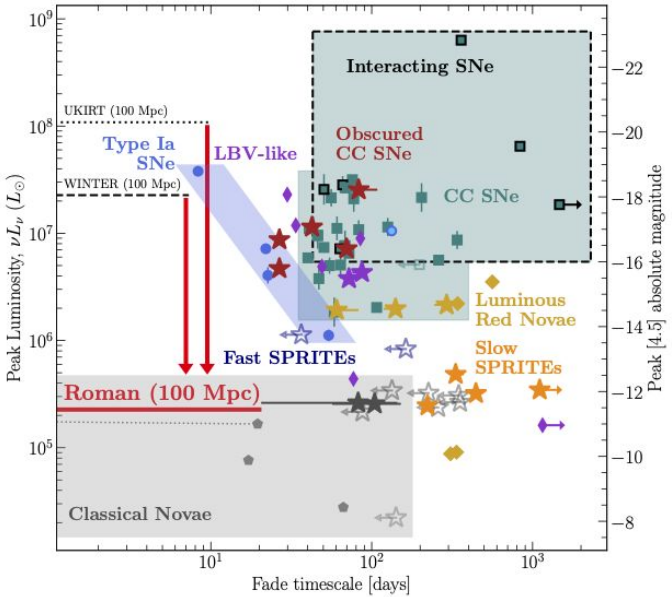
(Roman Alerts Promptly from Image Differencing)

A Roman Space Telescope Project Infrastructure Team (PIT)

Mansi Kasliwal (PI; Caltech)
Ben Rusholme (Pipeline Development Lead; IPAC)
Schuyler Van Dyk (Science Definition Lead; IPAC)
Roberta Paladini (Galactic transients, Inclusion Lead; IPAC)
Lin Yan (Testing and Validation Lead; Caltech)
Ashish Mahabal (Machine Learning Lead; Caltech)
Joe Masiero (Solar System Objects Lead; IPAC)
Russ Laher (Senior Applications Developer; IPAC)
Jacob Jencson (Testing and Validation Scientist; IPAC)
Amalia Rivera (Database Administration, Infrastructure; IPAC)
Siddarth Mohite (Applications Developer; IPAC)

RAPID Will Enable Roman Time Domain

Transient discovery in Roman HLTDS, HLWAS, GBTDS, and GAS



1000's of infrared transients will be discovered over every Survey field observation over a large range of redshift throughout the Roman mission

CCS: HLTDS=High-Latitude Time Domain Survey + HLWAS=High-Latitude Wide-Area Survey + GBTDS=Galactic Bulge Time Domain Survey (~75%)
GAS=General Astrophysics Surveys (~25%)

Our goal is to provide four services to the Roman community:

- Rapid image-differencing of every new Roman image from a reference image
- Prompt public alert stream of all Roman transient and variable candidates
- Source-matched light curve files for every identified Roman candidate
- Forced-photometry service for photometric history at any observed location

There was no existing plan by the Roman project to deliver a rapid time-domain discovery alert system

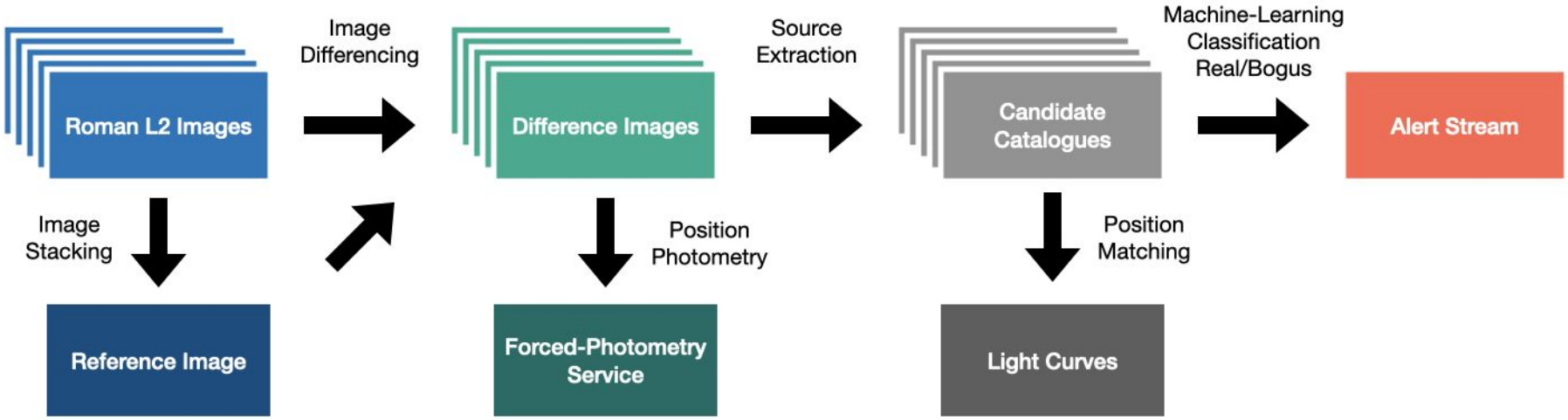
The Technical Plan

- Pull calibrated Level-2 WFI data from the STScI/SOC staging location (< 48 hour turnaround)
- Execute image differencing and prompt public alert broadcasting (< 1 hour)
  - ➢ Includes initial source classification via machine learning
- Offer forced photometry on difference images
- Append and release light curve history or sources

  ⎫ (< 24 hour)
- Archive public alerts via STScI MAST
- (All processing in the AWS Cloud)

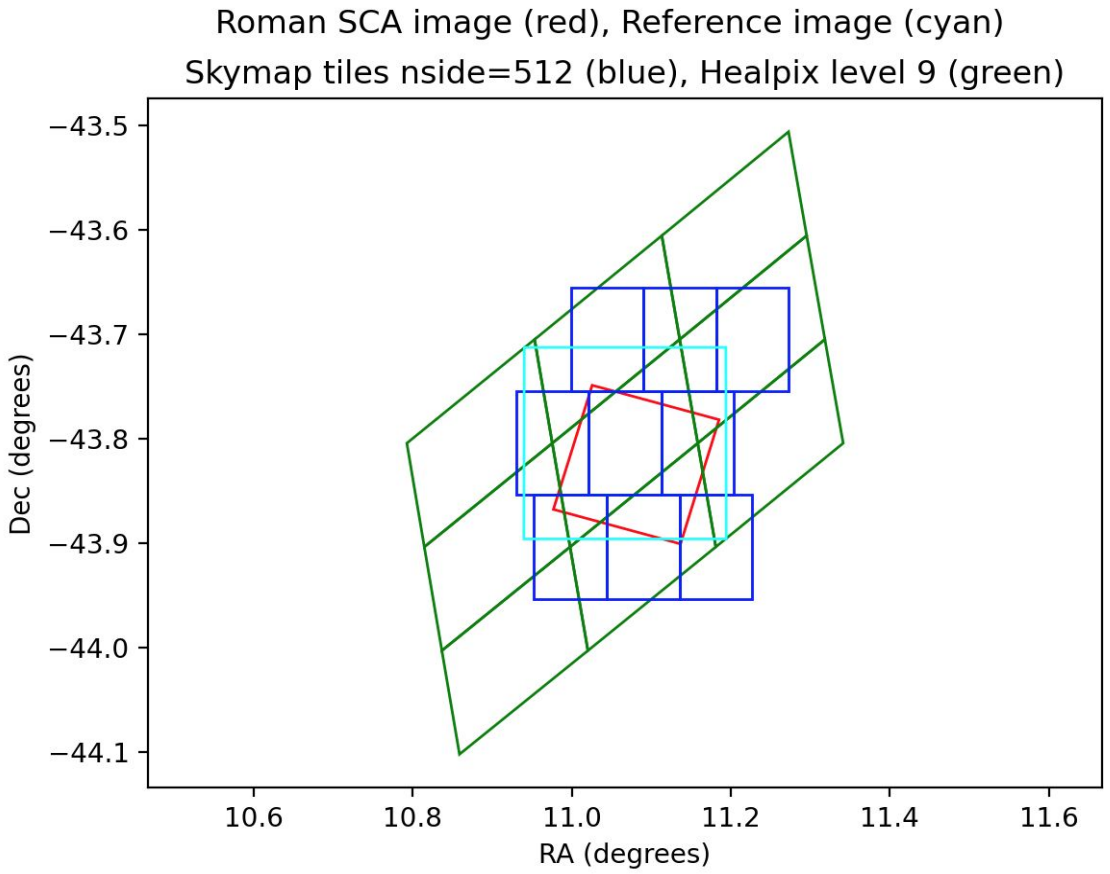
RAPID Pipeline Flow

Leveraging our previous experience with the Zwicky Transient Facility (ZTF)



End-to-end testing and validation

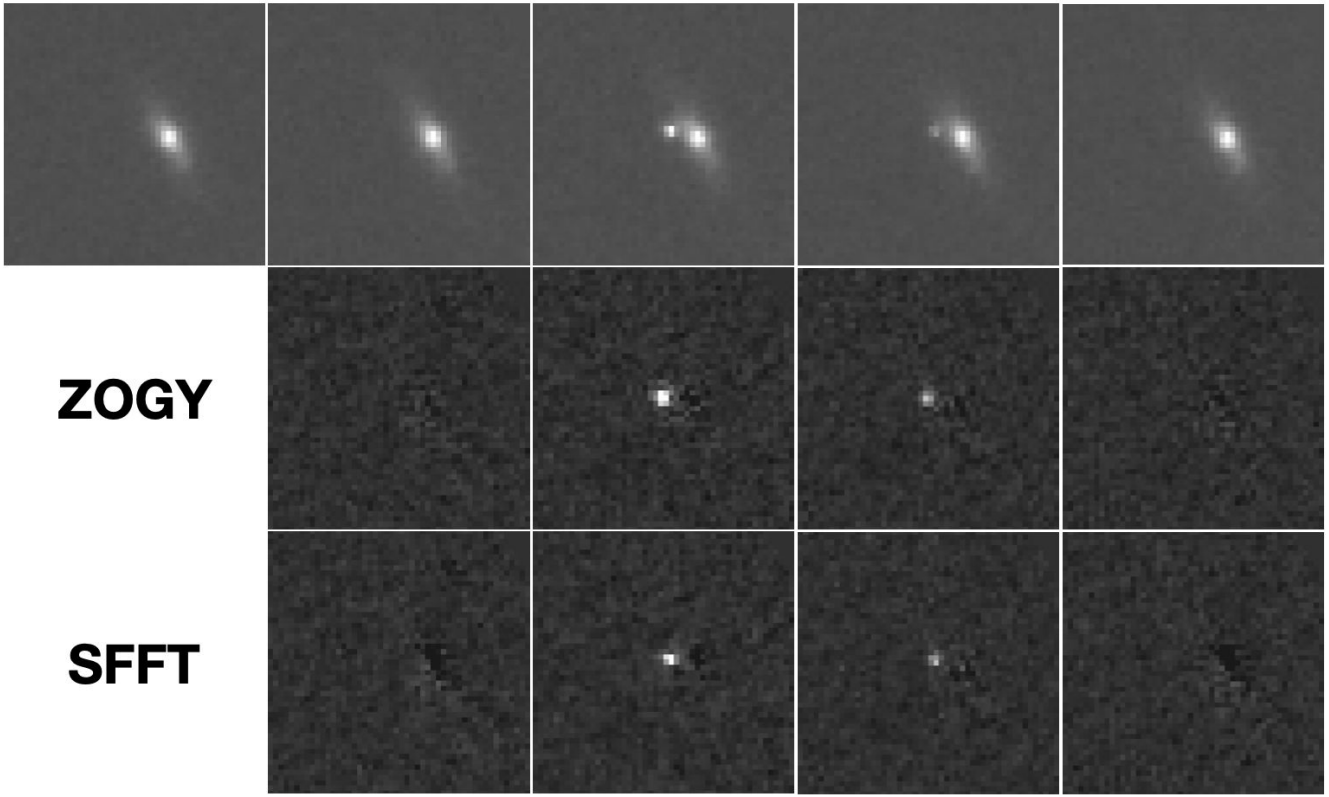
Reference image tiling scheme



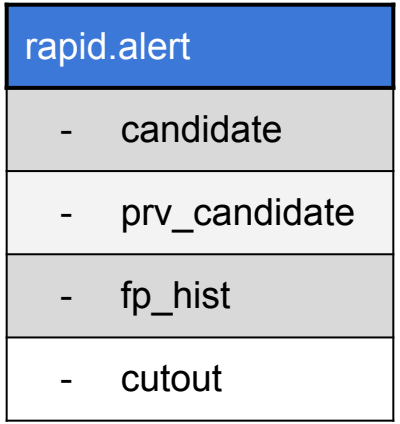
Subtraction Algorithm Comparison for down-select

Testing underway with, e.g., NASA OpenUniverse HLTDS Simulations

(Thank you Alina Kiessling, Michael Troxel, Dan Scolnic, Rebekah Hounsell, Rick Kessler)



Draft Alert Schema



Preliminary draft schema is available in GitHub repo

Forked from ZTF v4.02

Identical structure to Rubin

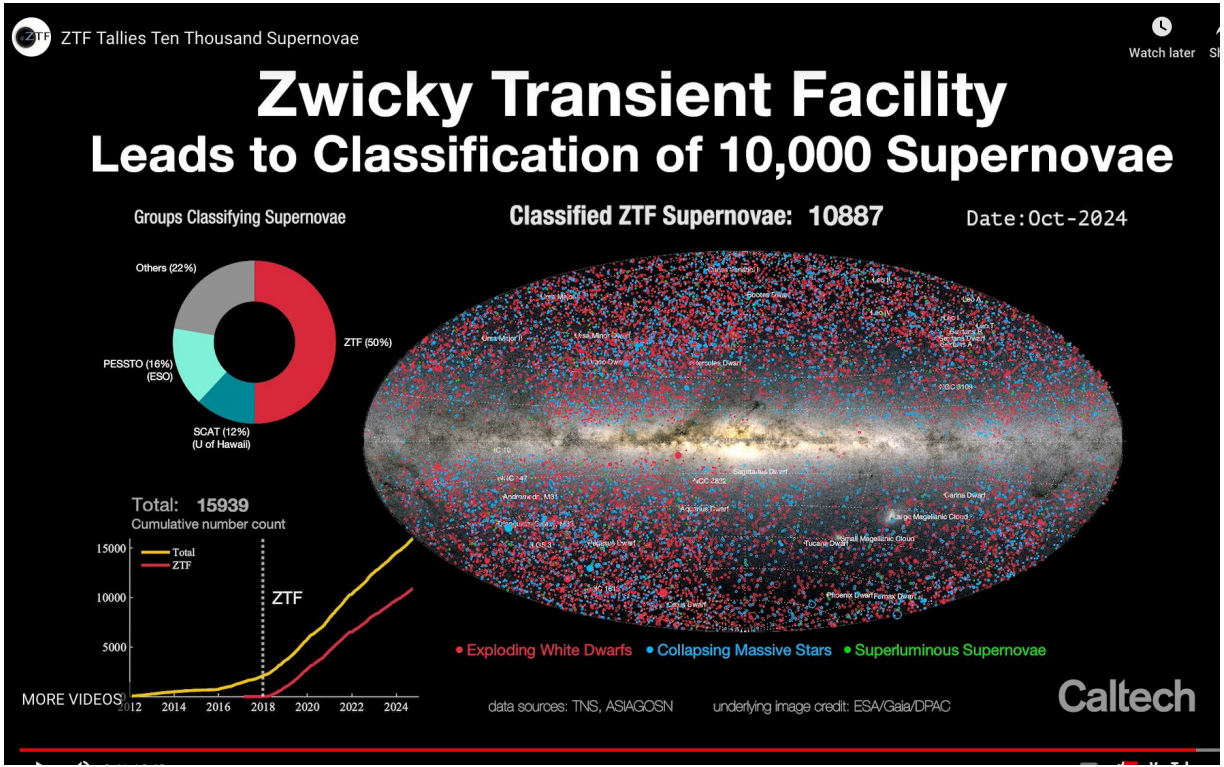
Majority of fields are matches to external catalogs TDB (Gaia, Rubin, Euclid, ...?)

Data Products/Deliverables

Product	Format	Distribution	Access
Simulated Images	ASDF	S3/MAST	Public
Reference Images	ASDF	S3/MAST	Public
Difference Images	ASDF	S3/MAST	Public
Alert Stream	Avro	Kafka	Public
Alert Archive	Avro/tarball	MAST	Public
Light Curves	Parquet	S3/MAST	Public

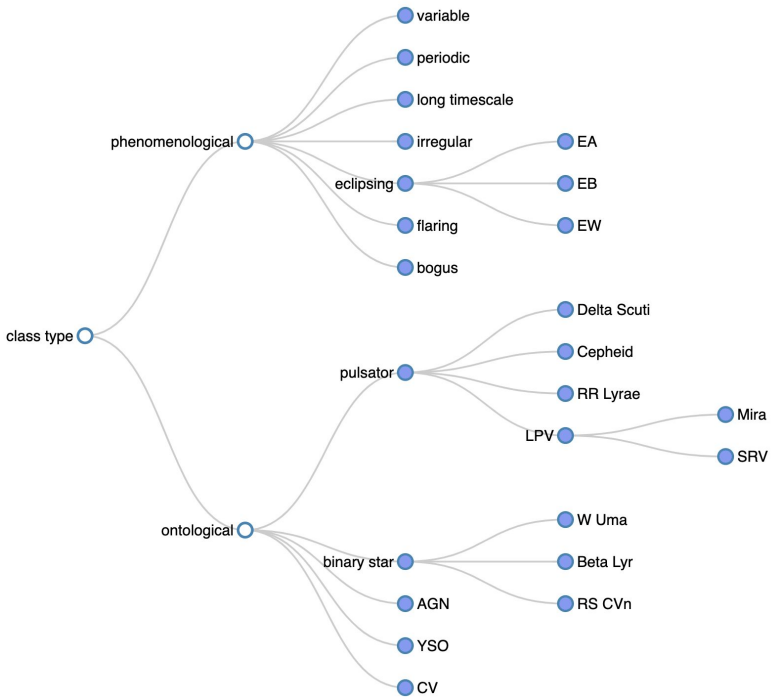
Motivation: The ZTF Bright Transient Survey

Dedicated spectroscopic follow-up is essential



https://youtu.be/lBeEAA_g-gc

Motivation: RAPID Source Classification via Machine Learning



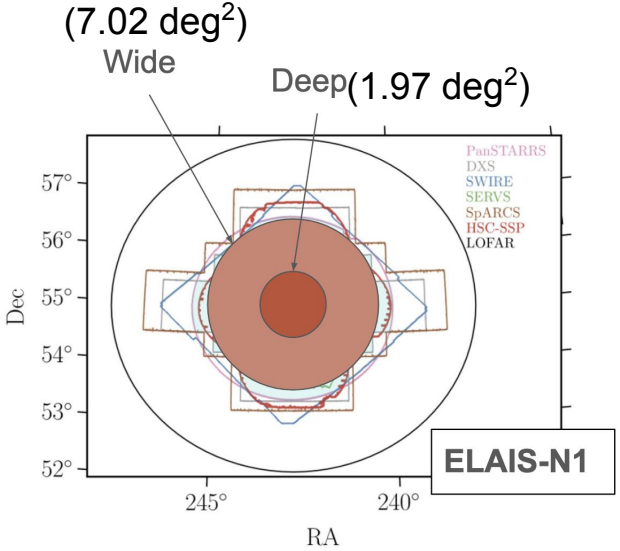
EA/EB/EW - classes of binaries; LPV - Long Period Variable; SRV - Semi-Regular Variable; AGN - Active Galactic Nucleus; YSO - Young Stellar Object; CV - Cataclysmic Variable; W Uma - W Ursa Majoris; RS CVn - RS Canum Venaticorum

- Hierarchical binary source deep-learning classifiers robustly and successfully implemented in ZTF
- Allows users to choose thresholds
- Real/bogus score to flag artifacts
- Classification included in alert packet
- Work to be done before launch to optimize classification for Roman
- ***Further refinement (improved training) can be accomplished via source spectroscopy***

We propose a *dedicated*, systematic magnitude-limited
PFS follow-up program of RAPID-discovered transients
Primarily, to obtain classification spectra

The observing time will be driven primarily by the HLTDS and the GBTDS
and, to a lesser degree, by General Astrophysics Survey (GAS)
programs with a time-domain component

High Latitude Transients (1)



Nominal (in-guide) selection of northern field from the Roman CCS HLTDS Definition Committee Report

~6 months total over two years for HLTDS

- Supernovae (Ia, core collapse)
- Luminous red novae (Mergers, Common Envelope Ejections)
- LBV massive star eruptions
- Tidal disruption events (TDEs)
- AGN flares
- Superluminous supernovae
- Pair-instability supernovae

Will also likely discover the fewer halo variables/transients

High Latitude Transients (2)

Obtain classification spectra of every possible RAPID-discovered transient with J$\lesssim$ 23 mag with multiple footprints to cover the northern HLTDS *once a month*

SNe Ia, SNe Ia-91bg, SNe Ib/c, SNe IIP/IIL: z $\lesssim$0.4
AGN: z $\lesssim$0.8; TDEs: z$\lesssim$0.6; SLSNe-I: z$\lesssim$1.8

TOTAL ~ 5739 of these transients within these redshift limits
~~38–120~~ 16 per sq. deg., ~~48–150~~ 20 per PFS science FoV per month
Would need ~~10~~ 9 PFS pointings to cover northern HLTDS

(Not including the less common transients, e.g., LRNe, LBVs, SLSNe-II, or the very high-redshift PISNe)
(We will miss some fainter transients before/after peak, but then gain others near max)

High Latitude Transients (3)

Every possible RAPID-discovered transient with J $\lesssim$23 mag
in the northern HLTDS *once a month*

- From PFS ETC, S/N(min)~1/pix in Near-IR arm in 1.5 hr (3 x 1800 s)
- ~~10~~ 9 pointings x 1.5 hr/pointing [~~15~~ 13.5 hours] x (6+6) months = ~~180~~ 162 hrs total

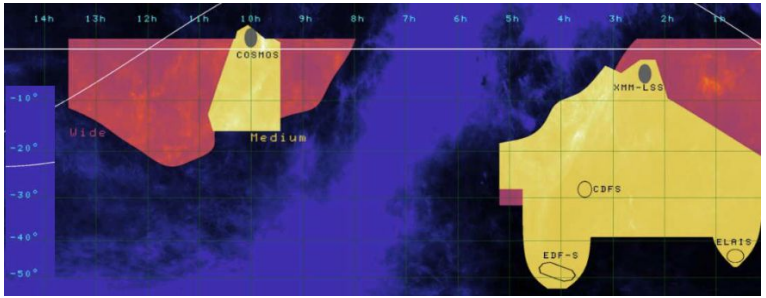
  (~6 months in Year 1, ~6 months in Year 2)
- **~~23~~ 20 (dark/grey) nights total**
- ~~150~~ 20 fibers x ~~10~~ 9 FoV's x ~~180~~ 162 hr ~ **~~270,000~~ 29,160 fiber hours**

Priority Order (High to Low): Classification of new live transients; multiple epochs of known transients; amplitude-ranked list of variable stars; if detected, host galaxy properties

High Latitude Transients* (4)

Every possible RAPID-discovered transient with J $\lesssim$23 mag
in the HLWAS Deep Tier (COSMOS, XMM-LSS; each 9.6 deg^2)
Visit twice: after 2nd and 3rd pair of passes

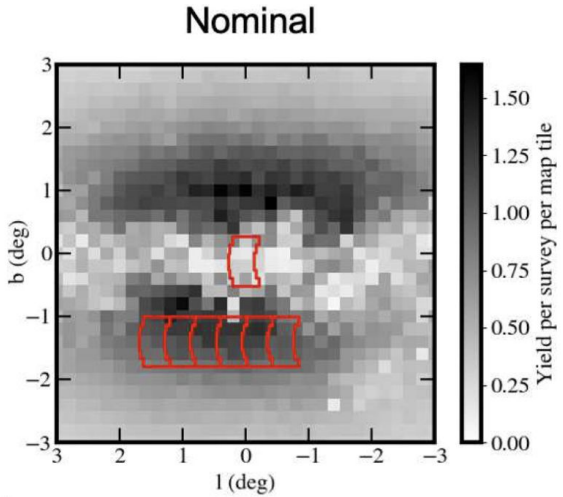
- Assume similar transient rates (~25-30 sources per FoV) and same exposure regime as HLTDS
- 16 pointings x 1.5 hr/pointing [24 hours] x 2 visits = 48 hrs total
- **~6 (dark/grey) nights total**
- ~30 fibers x 16 FoV's x 48 hr ~ **23,040 fiber hours**



Proposed survey fields from the Roman CCS HLWAS Definition Committee report

***new slide**

Galactic Bulge Transients(1)



Nominal survey fields from the Roman CCS GBTDS Definition Committee report

6 x 72-day seasons spread over all 5 yrs scheduled around HLTDS

- Eruptive YSOs (FUors, EXors)
- “Dipping giants”
- Classical novae
- Recurrent novae
- Dwarf novae
- Cataclysmic variables
- LMXBs and HMXBs
- Stellar (M dwarf) flares
- Pulsating variables
- Microlensing exoplanet events

Galactic Bulge Transients(2)

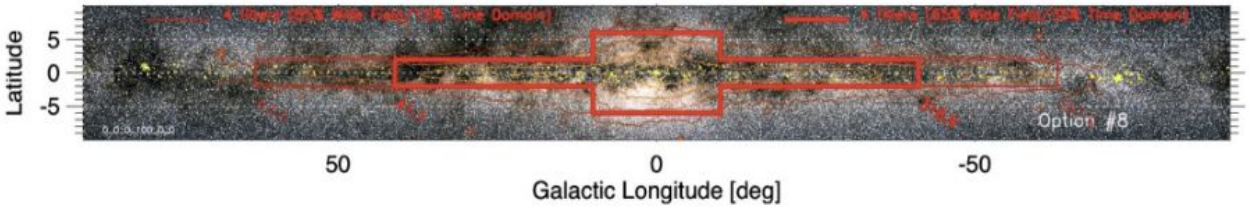
We would use ~2200 science fibers (based on dwarf flare numbers) to cover every transient with J~15–20 mag for 6 GBTDS fields (plus the Galactic Center) during all 6 seasons of the survey

Observe ~once a month per season
6 seasons (of 68.5 days each) x 2 nights/season = **12 nights total**
Need 2 PFS FoV to cover GBTDS fields + 1 FoV to cover GC

From PFS ETC, S/N(min)~1/pix, Near-IR arm in 1 hr (4 x 900 s)
~~9~~ 3 pointings x 1 hr/pointing [~~9~~ 3 hours] x 12 nights total = ~~108~~ 36 hrs total
~~**12 (grey/bright) nights**, ~1000 fibers x 9 FoV's x 108 hr ~ **972,000 fiber hours**~~
4.5 (grey/bright) nights, ~2200 fibers x 3 FoV's x 36 hr ~ **79,200 fiber hours**

Galactic Plane Survey*

Currently, this Early General Astrophysics Survey (GAS) is not completely defined – ~100-200 of the 700 total hours could be TDA-optimized, possibly split between early in Year 1 and then again late in Year 2



We tentatively propose to follow up ~10 TDA (Roman FoV-sized) fields early in Year 1 and at the end of Year 2

Assuming GBTDS exposure times, numbers of fibers, etc., we would require **~2.5 grey/bright nights**, or

~2200 fibers x 10 FoV's x (2 x 1 hr) ~ **44,000 fiber hours**

***new slide**

Summary(1)

- On behalf of the entire Roman time domain community, we propose a *dedicated*, systematic magnitude-limited PFS follow-up program, covering the full range of transients discovered by the RAPID pipeline in the northern HLTDS, the entire GBTDS, the HLWAS Deep Tier, and select northern GAS, including the Galactic Plane Survey (GPS)
- *Is it likely that a less-unified global follow-up (in the north) will be as complete or as adequate?*
- We still do not know the definition of the GPS
- We still do not know the deliberation results of the ROTAC
- *Which other GAS will enable TDA, if any, is currently unknowable*
- We tentatively estimate requiring ~2 additional nights for other GAS

Summary(2)

- Exptime estimates driven by the NIR spectrograph
- We anticipate using a subset of available science fibers
- The proposed program is driven primarily by the HLTDS and GBTDS
- Two main sets of fields are complementary in terms of scheduling
- We estimate that this program would require *nominally* **23+6+4.5+2.5+2= 35 nights** , spread out over the 6 months (in 2 years) of HLTDS, 6 x 72-day seasons of GBTDS, the Deep Tier passes of HLWAS, and 5 yrs of GAS
- The program would be designed and executed in collaboration with the SN PIT and RGES PIT, STRIDE WG, and the Roman TDA community
- The proposed program could well be combined with other PFS programs, e.g., HLTDS, SuPR, SPLASH, AGN demos, Red Giants