Design Considerations For a Roman Galactic Plane Survey

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Roman Early-Definition Astrophysics Survey (EDAS)

- In 2021 the Roman Project released a "Roman Early-Definition Astrophysics Survey (EDAS) Opportunity: Request for Information" (RfI) to solicit comments from the science community on (a) whether to pre-select any Astrophysics Survey, and (b) to outline and submit survey concepts that would demonstrably benefit from selection as an EDAS.

- The request instructed the community to submit a high-level conceptual description of a proposed survey using the Wide Field Instrument, to be executed within the first two years of the Roman mission, using up to ~ 700 hours of wall clock time (the equivalent of one full month).

Roman Early-Definition Astrophysics Survey Opportunity: Galactic Roman Infrared Plane Survey (GRIPS)

White Paper Submitted on October 22 2021

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See also submissions for Galactic Plane Survey concepts by:

- Thomas Kupfer (UT)
- Kishalay De (MIT)

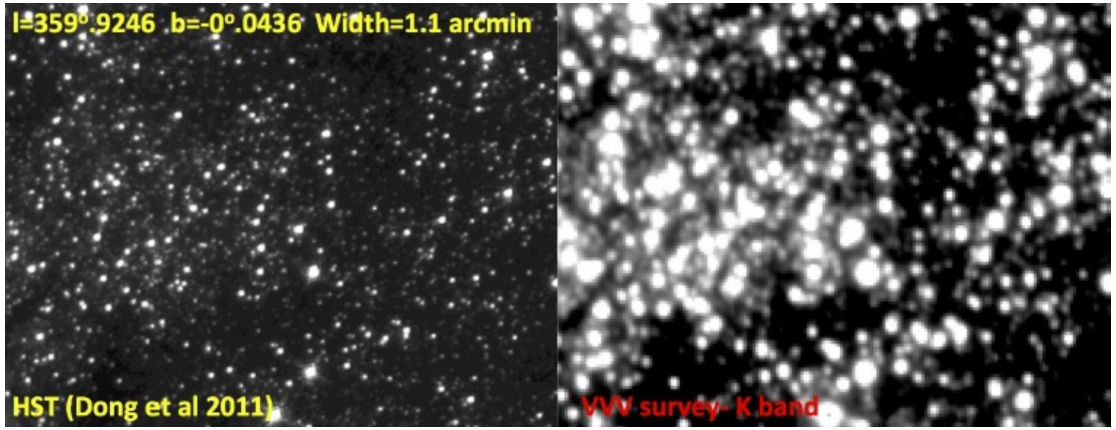
Motivation

Roman will be uniquely positioned to perform a survey of the Galactic Plane:

High angular resolution: of the inner Galactic Plane, only 2.8 deg^2 have been covered by HST. Roman will allow for the **identification of 120 billion sources,** a significant fraction of the Milky Way's stars. For comparison, this area contains only 0.38 billion sources in Gaia eDR3.

Sensitivity: With a K-band sensitivity limit of 22.85 (Vega) mags and assuming no extinction/source confusion, Roman/GRIPS can reach M_{Ks}=8.25 (M5V) for sources at the distance of the Galactic Center and M_{Ks}=12.5 (mid L dwarfs) for sources in M8 and M20. A solar type star could be detected on the far side of the Galactic disk, even with 2-3 magnitudes of absorption.

Mapping Speed: will allow for a significant fraction of the stars in the Galaxy to be covered in a uniform way, a crucial requirement for studies of Galactic structure.



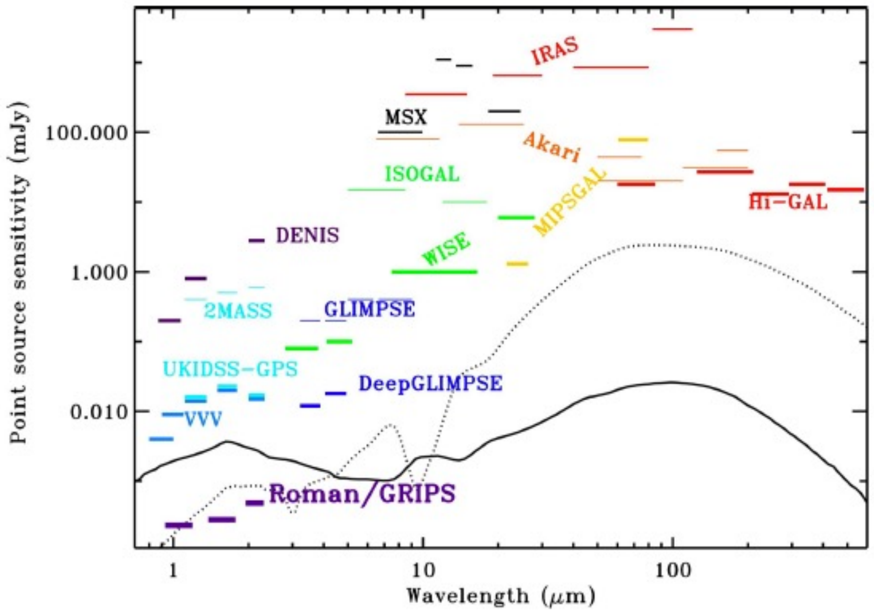


Figure Credit: Bob Benjamin

A Transformational Survey

Roman is uniquely suited to deal with the confusion and extinction prevalent in the plane of the Galaxy.

- **Unresolved Stellar populations:** GRIPS will enable studies of previously unresolved stellar populations (stellar clusters in star-forming regions, globular clusters).

- **Structure of the Galaxy – bulge / spiral arms:** Red clumps and YSOs can be surveyed out to a greater volume of the disk allowing the rewriting of Galactic structure, particularly the spiral arms and the central Galaxy where source confusion has blocked progress.

- **Stellar Initial Mass Function & 3D dust maps:** GRIPS will enable studies of the stellar initial mass function down to lower mass limits in sites across the Galaxy, and provide significantly more "background" sources for the construction of 3D dust maps.

January 6th 2024 – Part I

Recommendations for Early Definition Science with the Nancy Grace Roman Space Telescope

Robyn E. Sanderson,[1] Ryan Hickox,[2] Christopher Hirata,[3] Matthew Holman,[4] Jessica Lu,[5] and Ashley Villar[4]

"The committee found that there was sufficient justification to execute and Early-Definition Survey with the Roman telescope. ***The top ranked survey concept was a survey of the Galactic Plane****.* ***The Roman project plans to accept the recommendation*** *to proceed with an early definition astrophysics survey of the Galactic plane, and will set up a community process to define the specifics of this survey."*

"The committee considered an infrared survey of the inner Galaxy … to be unprecedented and potentially transformational, with impact across a very broad range of disciplines."

January 6th 2024 – Part II

Recommendations for Early Definition Science with the Nancy Grace Roman Space Telescope

Robyn E. Sanderson,[1] Ryan Hickox,[2] Christopher Hirata,[3] Matthew Holman,[4] Jessica Lu,[5] and Ashley Villar[4]

*"Such a survey would require a **high level of coordination between stakeholders** across multiple disparate subfields of astrophysics...*

*The early survey definition process would **ensure** that **survey area, cadence, and outcomes are defined collectively** by this broad community and **that the full breadth of science can be realized.***

***Evaluating trade-offs** between cadence and plane coverage will require a larger than usual time investment given the variety of relevant science cases."*

Trade-offs

- Filter Selection
- Cadence
- Dithering Strategy
- Coverage Area
- Balance between imaging vs. spectroscopy

Filter Selection

The filter selection is one of the most critical yet challenging trade-offs that will be studied.

Examples:

Science Case	Filters
Galactic Structure, Red Clumps	V, I, K (e.g., Alves et al. 2000)
Dust Extinction Curve	J, H, K
Brown dwarfs	R, J, K

Wide Field Instrument (WFI)

Astro2020 Science White Paper

The IMF at Very Low Mass using Near-IR Surveys from Space: The Need for Deep K-band Imaging

Thematic Areas: ☐ Planetary Systems ☑ Star and Planet Formation
☐ Formation and Evolution of Compact Objects ☐ Cosmology and Fundamental Physics
☑ Stars and Stellar Evolution ☐ Resolved Stellar Populations and their Environments
☐ Galaxy Evolution ☐ Multi-Messenger Astronomy and Astrophysics

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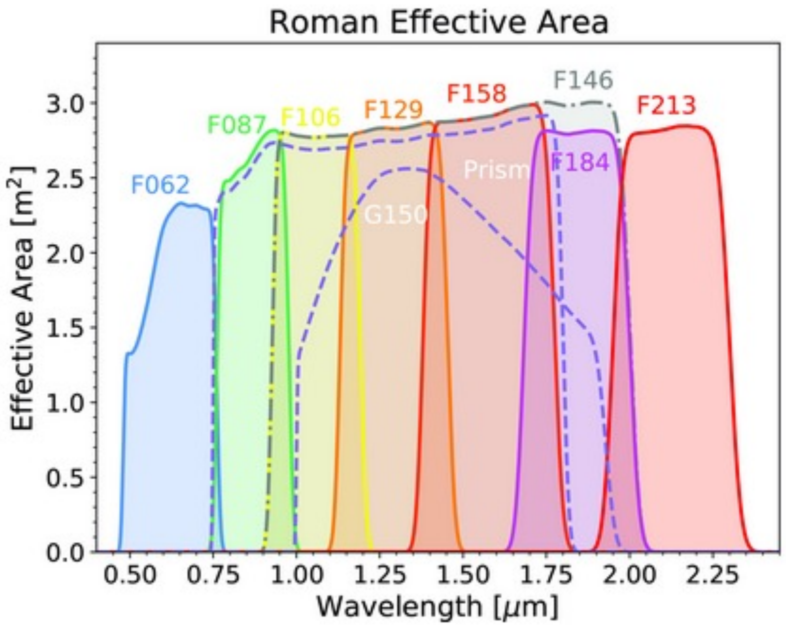


Cadence

The number and frequency of survey epochs is a complex trade-off between maximizing the information on proper motions and source parallax, on one hand, and survey depth and angular coverage.

The ability to identify and classify variable sources and transient phenomena critically depends on the cadence of the survey. *The timescales for rare occurrences like microlensing due to solitary black holes and exo-planetesimal collisions may be amenable to the cadences that provide* **proper motion knowledge** *while preserving a broad survey of the Galactic plane.*

The timing of epochs is also important to provide an appropriate lever arm for proper motion studies.

Dithering Strategy

At least **two dither positions** *are required in each filter to allow* ***for filling the gaps in the detectors and accounting for cosmic rays.***

However, **additional dithering increases the astrometric quality of the surveys and the sampling of the telescope PSF** *by the pixelization of the focal planes.*

Astrometric and photometric accuracy are strongly effected by how the data are collected with undersampled systems.

The major trade offs in this case are among dithering, coverage area and integration time: for a given integration time, more dithering implies less coverage area, and vice versa.

Coverage Area

The two fundamental options here are going deep or going wide.

One may chose to observe only a limited region of the Galactic Plane (a few deg2) but with lots of filters and dithering positions, or to cover a large area of the Plane.

In this case, the trade-off consists in selecting how wide this area should be: in principle, Roman could observe all four quadrants of the Galactic Plane in multiple filters, taking less than two months and reaching a depth of 25 mag per filter.

However, this wide coverage area would be at the expense of the number of allowed dithering positions, and thus a reduced astrometric accuracy

Imaging vs. Spectroscopy

Roman has very powerful imaging capabilities in terms of resolution, sensitivity, and mapping speed.

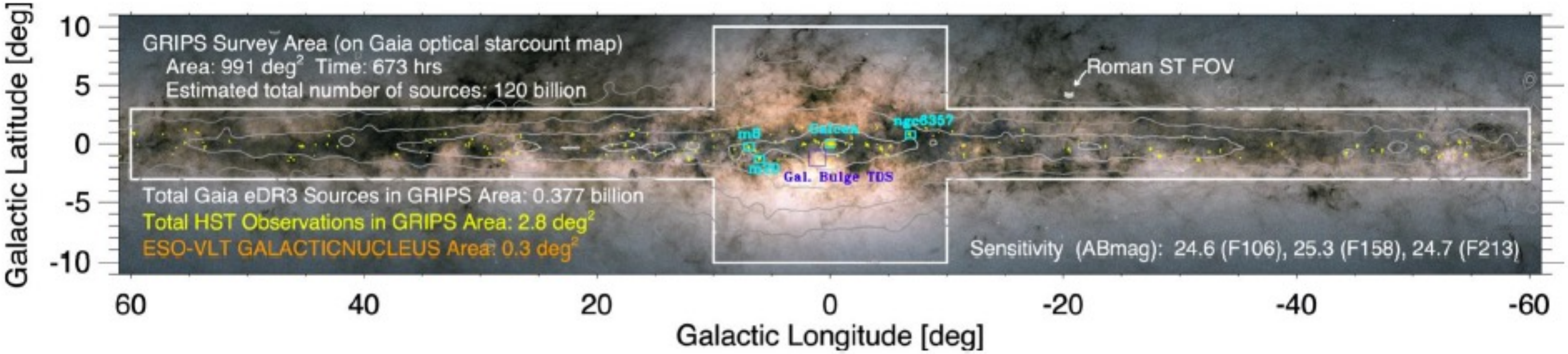
However, ***the WFI grism also provides an opportunity to perform a spectroscopic survey****. Recently, the JWST/NIRCam grism has demonstrated that slitless spectroscopy is feasible in crowded fields (e.g., JWST Program # 1188, P.I. K. Hodapp).*

This opens up the possibility of performing an imaging survey with complementary spectroscopic observations.

These would allow, for instance, the identification of different classes of objects, such as YSOs and evolved stars, and for stellar parameter and abundance measurements of valuable highly-extinguished sources.

Possible Observational Outline

Performed by: Catherine Zucker & David Nataf



Coverage: $-60^0 < l < +60^0$, $|b| < 3^0$ (inner Galaxy + bulge) - ~1000 deg^2 total

Filters: F106, F158, F213 (roughly, JHK)

Integration Time: 55 sec / filter → minimum depth: 25.5 mag, 25.3 mag, 24.7 mag (F106, F158, F213, respectively)

Dithers: one primary dither (filling detectors gaps + cosmic-ray removal) and two secondary dithers (F213, accurate astrometry)

Total: 673 hrs

Defining Performance Metrics & Community Involvement

- *In order to evaluate the ability of a specific survey strategy to address one or more science cases,* **we will have to define a set of quantitative metrics.**

These metrics may include, for instance, the accuracy with which a given survey plan can successfully allow the retrieval of the location of specific density features (e.g., the bar) from a simulated data set, or can measure a reconstructed extinction curve consistent with the one used as an input.

- ***The ultimate design of GRIPS will require substantial community input to optimize the survey*** *and its returns.* ***Defining the survey early will allow us to build not only the most powerful strategy to address different science cases on its own, but also a well-crafted initial design to enable optimal expansions in epochs, spatial coverage, and wavelength coverage by subsequent guest investigators.***