Galactic Surveys WFIRST/AFTA Style

Lynne A. Hillenbrand (Caltech)

[with some borrowing of material]


STARS ONLY

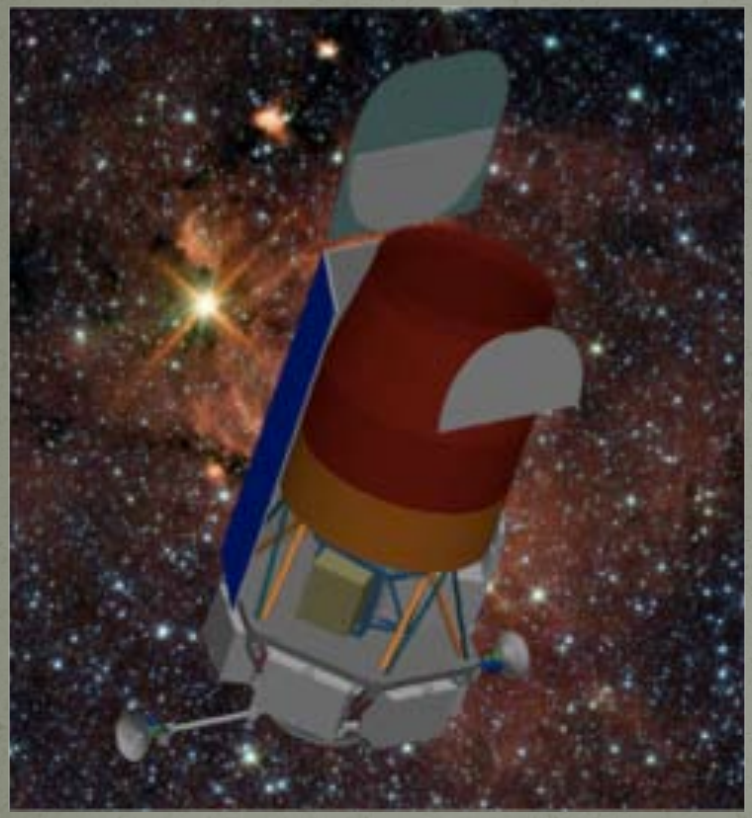
Why Survey, and What Parameters Matter?

- Surveying and measuring the sky has been part of astronomical culture since antiquity.
- We are mostly a discovery-driven science.
- Technology advances lead to scientific advances.
  - depth
  - spatial resolution
  - areal coverage
  - data storage / dissemination

WFIRST will take the next steps in all of these areas!

WFIRST AFTA

- WFIRST: Wide-Field Infrared Space Telescope
- AFTA: Astrophysics Focused Telescope Asset



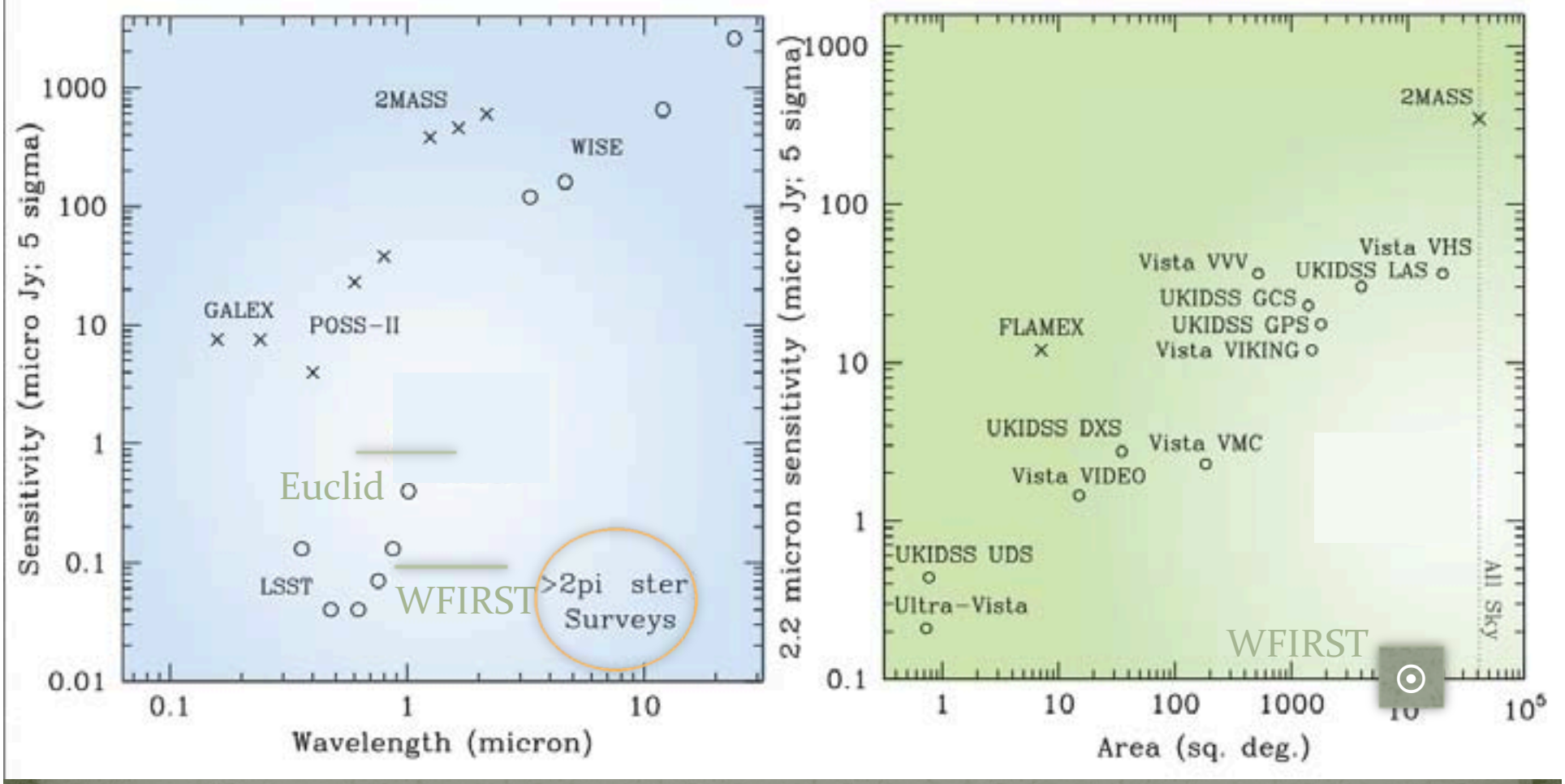
- 2.4 m TMA (former NRO telescope)
- 18 H4RG detectors
- 0.11" / pix

- 0.7 - 2.0 micron bandpass ***
- 0.28 sq. deg FoV

- 4 filter imaging; grism + IFU spectroscopy
- wide high latitude survey: 2000 sq. deg., ~27 mag AB
- R~600 grism + R~100 IFU
- grism survey depth: 3 x 10^{-17} erg/cm^2/s (3.5σ)

- 5 year baseline mission

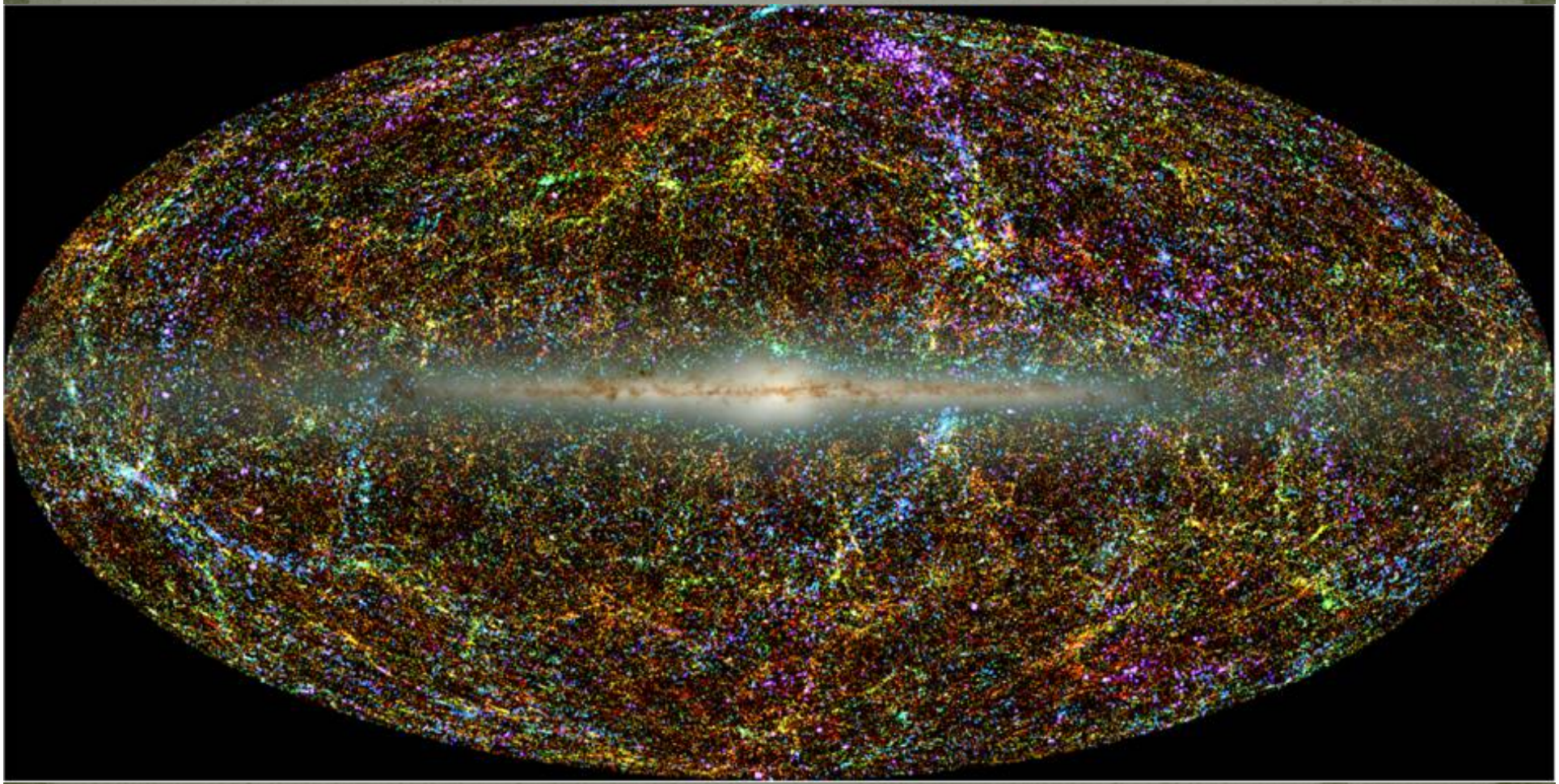
credit: Dan Stern + SASIR team

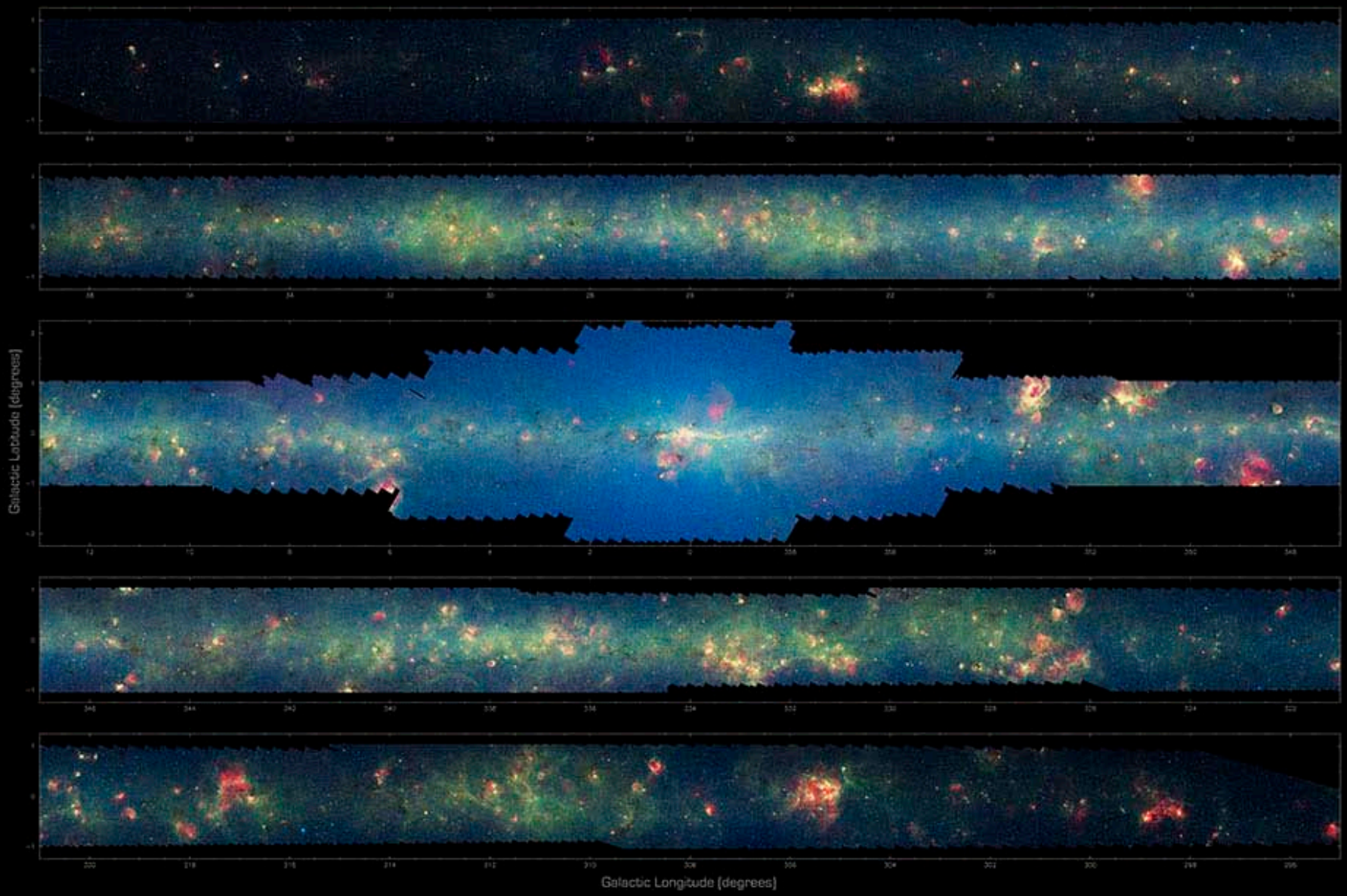


WFIRST and LSST together are a powerful combination – also in spatial resolution gains

Need to go to space for infrared sensitivity

2MASS stars and galaxies





The Infrared Milky Way: GLIMPSE/MIPSGAL Spitzer Space Telescope • IRAC • MIPS

NASA / JPL-Caltech / E. Churchwell (Univ. of Wisconsin), GLIMPSE Team & S. Carey (SSC-Caltech), MIPSGAL Team ssc2008-11a

What is best done at Near-IR vs longer or shorter wavelengths?

- Optimal in near-infrared
  - MLT dwarfs/subdwarfs
  - GKM giants and CSR stars
  - obscured and distant cepheids, RR Lyr, etc
  - ground truth for objects detected at longer/short λ
- Optimal longer than 2.5 um
  - Y dwarfs
  - dusty objects
  - objects in and behind dust obscured regions
- Optimal shorter than 1 um
  - BA subdwarfs
  - white dwarfs
  - extinction mapping

Highlights Enabled by Recent Surveys

- spiral arm and molecular cloud structure; extinction maps
- improved understanding of metallicity evolution and sfh
- many newly cataloged star clusters and sfr's
- primordial and debris disk statistics and evolution
- new insight into dusty evolved stars
- increasingly cooler and lower mass objects found (L ➔T ➔Y)
- discrepancies resolved between young cluster and field IMF
- kinematic distances; identification of "moving groups" and high velocity stars; cluster membership
- robust variable star statistics; catching outbursting objects (young stars, cv's, novae) in the act; eclipsing binaries across the HR diagram; microlensing

Near-Infrared Deep Survey Science

- galactic structure on all scales (stars, extinction/ism)
- galactic stellar pops and star formation history
- magellanic clouds and local group galaxies sfh
- star clusters and star forming regions in plane
- young stars
- dusty evolved stars
- faint red objects (brown dwarfs ➔ planetary masses)
- (initial) mass function
- proper motions, *and parallaxes* for nearby objects
- time domain studies, e.g. a galactic supernova

What will be left for WFIRST to do in the Galaxy?

- wavelength complement SEDs blue of Spitzer/GLIMPSE + WISE and red of LSST
  all kinds of science possibilities when measuring (cool) stars at peak of SED

- push field brown dwarf detection to the end of the IMF
- open cluster membership and IMF to 5-10 M_{jup} from deep+wide approach (+ p.m.)
- globular clusters and helium white dwarfs
- stellar streams, especially close to and through the galactic plane
- proper motions for bulge and halo stars
- high resolution extinction maps, even better when combined with GAIA + LSST
- advances in galactic structure, especially far side
  inner galactic plane likely confusion-limited so initially plan for $|l| > 30$ GPS

- spectroscopic surveys !!

Actual Galactic and Nearby Exgal. Science Cases

- http://wfirst.gsfc.nasa.gov/science/WFIRSTSurveyScience.pdf

Planetary Bodies

- *A Full Portrait of the Kuiper Belt, Including Size Distributions, Colors, and Bimodality*
- *The Outer Solar System from Neptune to the Oort Cloud*
- *Free-floating Planets in the Solar Neighborhood*
- *Measuring Planet Masses with Transit Timing Variations*
- *Exoplanet Spectroscopy with WFIRST*
- *WFIRST: Additional Planet Finding Capabilities – Astrometry*
- *WFIRST: Additional Planet Finding Capabilities – Transits*

Stellar Astrophysics

- *Stellar and Substellar Populations in Galactic Star Forming Regions*
- *Identifying the Coldest Brown Dwarfs*
- *Stellar Fossils in the Milky Way*
- *The Infrared Color-Magnitude Relation*
- *Finding the Closest Young Stars*
- *The Most Distant Star-Forming Regions in the Milky Way*
- *Super-resolution Imaging of Low-mass Stars with Kernel-phase and Precision Wavefront Calibration with Eigen-phase*

Galactic Astrophysics and the Local Volume

- *Proper Motions and Parallaxes of Disk and Bulge Stars*
- *Quasars as a Reference Frame for Proper Motion Studies*
- *The Detection of the Elusive Stellar Counterpart of the Magellanic Stream*
- *Near-field Cosmology: Finding the Faintest Milky Way Satellites*
- *The Mass of the Milky Way*
- *Distinguishing Between Cold and Warm Dark Matter with WFIRST*
- *Finding (or Losing) Those Missing Satellites*
- *Mapping the Potential of the Milky Way with Tidal Debris*
- *Dissecting Nearby Galaxies*
- *Galaxy Evolution from Resolved Stellar Pops: Halo Age Distributions of the Local Volume*
- *Substructure Around Galaxies Within 50 Mpc*
- *Resolved Stellar Populations in Nearby Galaxies*
- *Deep Surface Photometry of Galaxies and Galaxy Clusters*

Capabilities of Interest for Galactic Science

- exactly where you point/survey actually matters
- useful coverage of stellar SED

  - let's talk about a K-band!

  - even if not optimally sensitive b/c of telescope heating, we'll take it.
- grism spectroscopy

  - interesting everywhere confusion allows, esp. for low mass objects
- proper motions of known and newly discovered objects

  - GAIA + LSST will cover r = 6 to 24+, but infrared needed
- time domain possibilities

  - repeated deep/accurate coverage of selected regions

  - some (not all) science would require rapid response follow-up

Filter choice dictates achievable science

- Neither WFIRST nor Euclid is base-lining any version of a real K-band (2.2 um) filter.
- *This is "non-optimal" for many/most galactic astronomy science cases since for stars will need to separate T_* from A_V by spanning H- opacity minimum.*
- Simple calculation:
  - Going from 2.0 to 2.2 um reduces sensitivity by 4.5x
  - But going from 1.3m to 2.4m telescope increases by 3.5x

Guest Observer Capabilities						
1.4 years of the 5 year prime mission						
	Z087	Y106	J129	H158	F184	W149
Imaging depth in 1000 seconds (m_{AB})	27.15	27.13	27.14	27.12	26.15	27.67
t_{exp} for $\sigma_{read} = \sigma_{sky}$ (secs)	200	190	180	180	240	90
Grism depth in 1000 sec	S/N=10 per R=~600 element at AB=20.4 (1.45 μm) or 20.5 (1.75 μm) t_{exp} for $\sigma_{read} = \sigma_{sky}$: 170 secs					
IFU depth in 1000 sec	S/N=10 per R~100 element at AB=24.2 (1.5 μm)					
Slew and settle time	chip gap step: 13 sec, full field step: 61 sec, 10 deg step: 178 sec					

credit: SDT

Spectroscopic Capabilities Critical

- spectroscopy moves us from pictures and Hess diagrams to physics
- spectroscopy removes many degeneracies for stars
  - metallicity
  - surface gravity
  - effective temperature
  - distance
  - extinction
- grism approach most useful for low mass objects

Summary

- Proliferation of large scale mid-infrared, near-infrared and optical surveys over last decade, beginning with 2MASS.
- Nevertheless spatial gaps in modern near-infrared surveying to limit ~18-20'th mag remain. Improving to 25'th or beyond sounds fabulous to any galactic astronomer.
- The coverage and depth of WFIRST will be unprecedented.
- A "silver bullet" case within galactic science is not yet well-articulated. Also, thinking less evolved than for DE / uL.
- Improved depth/precision in near-infrared photometry and astrometry leads to new science. This is going to be great!
- There are innumerable areas of potential interest for GOs.
- Filter choices should be made with all communities in mind.

12 minutes including questions

- Galactic Science with WFIRST
- Lynne Hillenbrand
- California Institute of Technology, Pasadena, CA, United States.
- Large-scale digital sky surveys have come of age over the past decade. Existing data sets and future capabilities in infrared survey work relevant for galactic science will be summarized, along with the main science drivers.