The WFIRST Interim Design Reference Mission

Capabilities, Constraints, and Open Questions

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Disclaimer

• The capabilities and constraints described herein are for the Interim Design Reference Mission
  – Which evolved from the JDEM Omega RFI design
  – Which evolved from the SNAP/DESTINY/ADEPT mission concept studies and consultation with the Science Coordination Group

• The mission will continue to evolve in response to pressures of natural selection
Mission Description

• L2 Halo orbit
  – ~8 \(10^5\) km radius
  – 25°-35° Earth-Sun angle

• 5 year mission life
  – 10 year consumables

• DSN for communications

• Data Center at IPAC
Sample Survey Program

• Wide Survey: 11,000 deg$^2$ per year
  – Optimized for galaxy redshift survey
• Deep Survey: 2,700 deg$^2$ per year
  – Optimized for weak lensing
• Deeper synoptic survey(s): 1.44 deg$^2$, 5.76 deg$^2$
  – 5-day revisit cadence for SNIa ($z<1.2$, $z<0.8$)
  – *Ranga Ram Chary talk yesterday: 1-10 PISN/deg$^2$/yr*
• Galactic bulge: 7 fields, 2.04 deg$^2$
  – 15 minute revisit cadence, nonstop over 72 days, for planetary microlensing
• Galactic plane survey
• Guest Observer program
Some Fine Print

• **Deep Survey**
  – 5 steps equal to detector gap size, 160 sec per exposure
  – Uniform ImC depth: 5 exposures at all points
  – Repeat for second filter, at 5° roll offset
  – Third filter at shallower depth

• **Wide Survey**
  – 2 steps to fill gaps, 150 sec per exposure
  – Repeat for second filter, at 5° roll offset
  – Stacking all data from both SpCs gives 6 out of 8 exposures at most points in survey
  – 30 deg² per day

• **No synoptic repeat visits planned for these surveys**
Payload

• **Telescope:** 1.3m un-obscured TMA

• **Three instrument channels**
  
  – **Imager:**
    • 7x4 H2RG HgCdTe, 0.18” arcsec/pixel
    • 5 filters plus R~75 prism for slitless spectroscopy
    • 0.76μm – 2.0μm
  
  – **2 Counter-dispersed slitless spectrometers:**
    • 2x2 H2RG HgCdTe, 0.45”/pixel
    • R~230 (pt src, 2 pix resel), or 1250-1500 km/s/arcsec
    • 1.1μm – 2.0μm
Payload field of view
Optical layout

Cold side

Sun side

SpC TMs

SM

ImC

Filter Wheel

Pickoff Mirrors

SpC-B

PM

AuxFGS

SpC-A

ImC

2/15/12

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Plot shows Effective area for each filter and each SpC.

SN prism throughput is \(~5\%\) lower than the filters.

BAO prism throughput is higher in single-channel design.

Det QE used here may be optimistic below \(~1.3\mu m\).
**System PSF**

- **ImC Net PSF:**
  - (includes jitter, charge diffusion, pixelization, etc)

<table>
<thead>
<tr>
<th>Filter</th>
<th>R(EE50) arcsec</th>
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<tr>
<td>F087</td>
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<tr>
<td>F178</td>
<td>0.18</td>
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SpC is under-sampled, but pixel scale is adequate for a galaxy redshift survey.

- **Design residual wavefront error:**
  - **ImC:** 13-18nm rms (map above)
    - Observatory budget: 83 nm
  - **SpC:** 35-73nm RMS
    - Observatory budget: 213 nm
Observing Zone:
54°-126° Pitch off Sun Line
360° Yaw about Sun Line
±10° roll about LOS
(off max power roll*)

* Larger roll allowed for SNe

SNe Inertially Fixed Fields must be within 20° of one of the Ecliptic Poles, and can be rotated every ~45 days

Can observe Inertially Fixed Fields in the Galactic Bulge (GB) for 72 days twice a year
Scientific Pointing Constraints (scheduling)

• Microlensing campaigns can’t be interrupted
  – 72-day campaigns twice a year; 7 campaigns total
• SNIa campaign can run at low duty-cycle (say one day out of five), but last two years.
• We could almost, but not quite, get both of these to fit in a five year plan.
• SNIa requires constant roll for 45 day intervals
  – interleaving with WL may be problematic due to abrupt changes in thermal environment
• Galactic plane survey conflicts w/microlensing
Galactic Plane Visibility

Galactic Plane Visibility vs. Day of Year

Day of Year

Galactic Longitude

Galactic Plane Visibility

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Pointing Performance

• Pointing jitter: < 40 mas rms, per axis
• Revisit accuracy: ~18 mas
  – Limited by settle time
• Short slews (survey steps): <60s, 30s goal
• Long slews: 180° in < 10 minutes
• The antenna is on a gimbal, so no observing time is lost to downlink
• Unload momentum by hydrazine thrusters
Dynamic Range

• Detectors will be read non-destructively, with frame-time of 1.3 seconds.
  – If 3 samples desired prior to saturation, can observe AB ~13 stars (AB~14 in W149)
  – Cosmic-ray rejection on-the-fly
    • List of CR corrections will be downlinked
### WFIRST

<table>
<thead>
<tr>
<th></th>
<th>WIDE</th>
<th>DEEP</th>
<th>SNIa-1</th>
<th>SNIa-2</th>
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<td><strong>Imaging: 5σ point-source limiting magnitude (AB)</strong></td>
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<td>24.8</td>
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<td><strong>Spectroscopy: 7σ limiting line flux (10^{-16} \text{ergs}^{-1} \text{cm}^{-2} \text{s}^{-1} )</strong></td>
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Galactic Bulge nominal 5σ limiting magnitude = 30.2, but real limit is crowding Spectroscopic limit is for galaxies with R(EE50)=0.2”

Euclid limiting sensitivity (from Red Book):
- Imaging 5σ point source in YJH: 24 (AB)
- Spectroscopy 3.5σ point source: 3.0 $10^{-16}$ \text{ergs}^{-1} \text{cm}^{-2} \text{s}^{-1}$
Open Questions

• Bandpass: looking at extending to ~2.4μm
• Single channel optical design
  – Add prism wheel, move SpC detectors to ImC
  – Imaging faster, redshift survey slower; total time similar
    • Faster imaging relieves scheduling conflicts
  – More flexible for tailoring observing program
• 4kx4k detectors with 10μm pixels
  – Relieves conflict between fine sampling and large FoV
  – Readout slower -> fewer samples -> higher readnoise and fainter bright limit.
• IFU for SNIa spectroscopy
  – Cost benefit trades are complex
Single Channel Design

The Field of view of the single imaging & spectroscopy channel is shown to scale with the Moon, HST, and JWST. Each square is a 4Mpix vis-NIR sensor chip assembly (SCA)

ImC: 9x4 @ 0.18"/p;

489°

1.084°

Each square shown is physically a 2040 x 2040 x 18um HgCdTe array [H2RG-18]

Moon (average size seen from Earth)