

WFIRST Project Activities

Neil Gehrels
WFIRST Project Scientist
NASA-GSFC

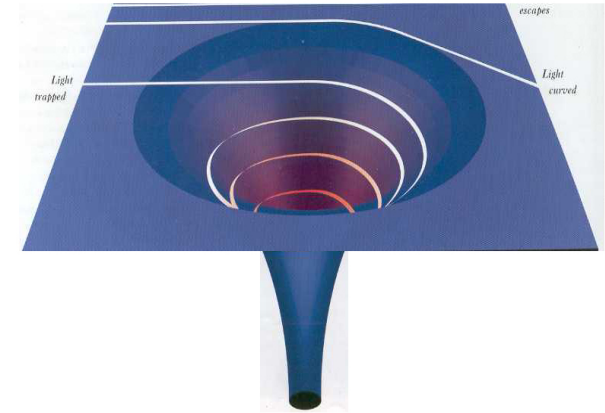
IPAC – Wide-Field IR Science
February 15, 2012

Outline

- Project history
- Concept development and costing
- Scientific requirements flowdown
- GSFC-JPL-IPAC team
- Detector development
- Simulations
- Schedule to launch
- Science outreach



General Relativity



- Einstein General Relativity connection to WFIRST through
- field equations, cosmological constant
 - gravitational bending of light (weak lensing, microlensing)

$$G_{\mu\nu} = (8\pi G/c^4) T_{\mu\nu}$$

WFIRST History

JDEM

- 1998: Discovery of accelerated expansion of the universe
- 2006: 3 teams selected for study (ADEPT, DESTINY, SNAP)
- 2008: NASA & DOE formulate JointDEM as a strategic mission
- 2009: JDEM proposed to Astro2010

MPF

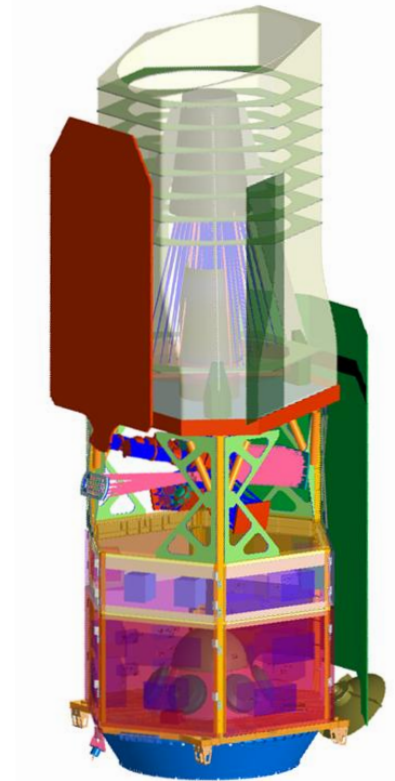
- 1998: Mather suggests space application of microlensing at Notre Dame
- 2004-2006: MPF proposed as Explorer and Discovery
- 2009: MPF proposed to Astro2010

NIRSS

- 2009: NIRSS proposed to Astro2010
- 2009: 14 white papers submitted on wide-field IR survey science

WFIRST

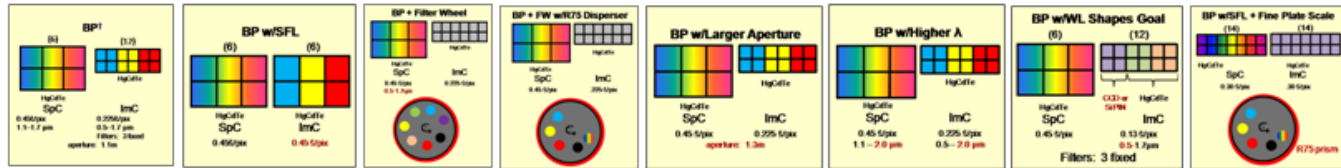
- 2010: WFIRST ranked 1st in large mission category by Astro2010
- 2011: Science Definition Team formed to study WFIRST
- 2011: Nobel prize for acceleration of universe
- 2011: Free-floating planets detected by ground microlensing
- 2012: WFIRST science conference at IPAC



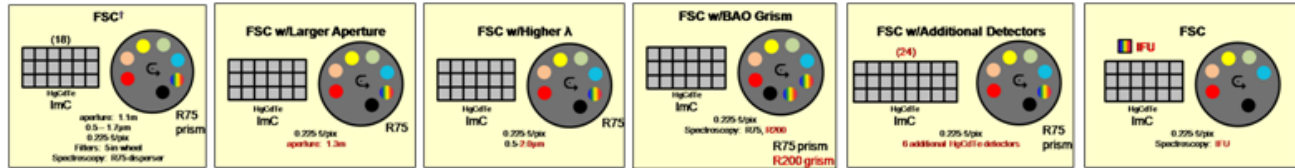
JDEM-Omega

Over 80 Concepts Developed

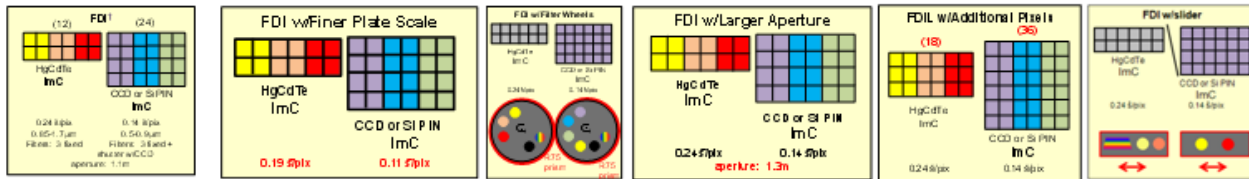
1. Benchmark Probe (8 of 18 cases shown)



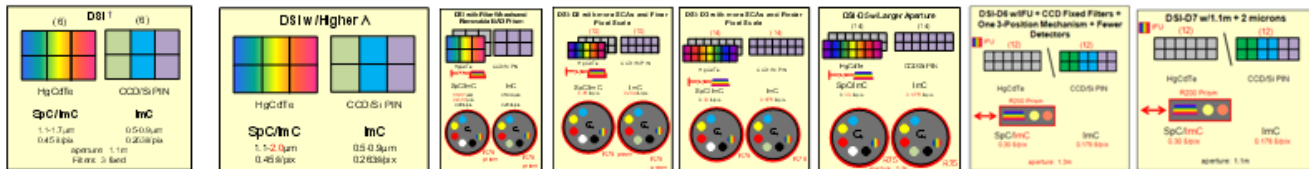
2. Focal Single Channel Imagers (6 of 11 cases shown)



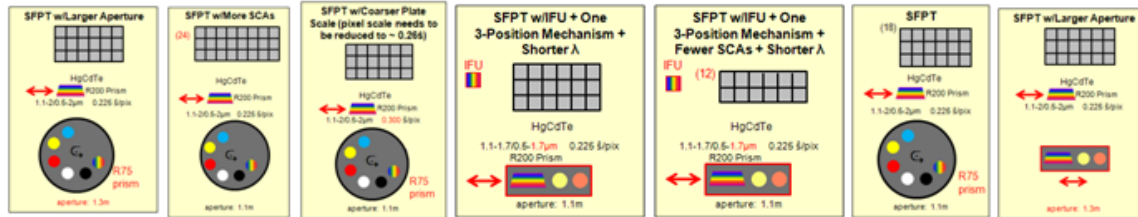
3. Focal/ Dichroic Imagers (6 of 10 cases shown)



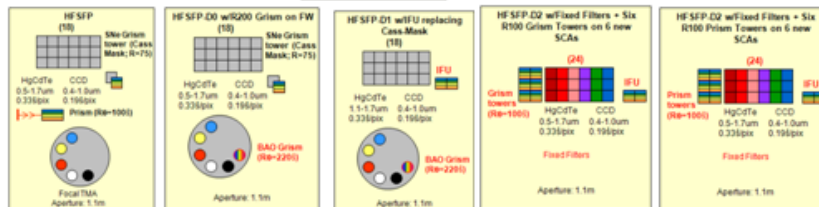
4. Dichroic Spec/Imager (8 of 10 cases shown)



5. Single Focal Plane Transformer (7 of 7 cases shown)



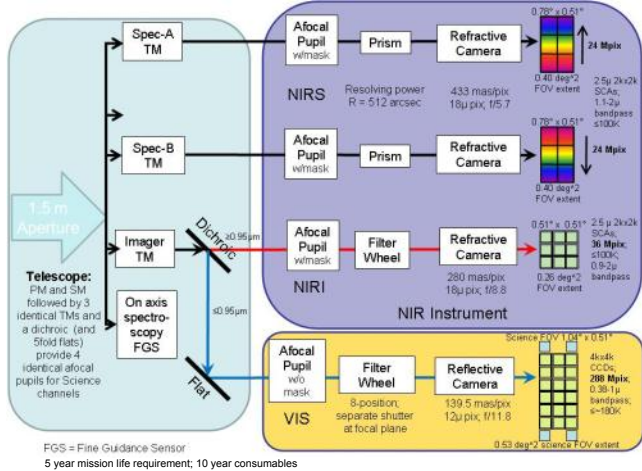
6. Heterogeneous Focal Single Focal Plane (5 of 5 cases shown)



JDEM - WFIRST DRM Evolution

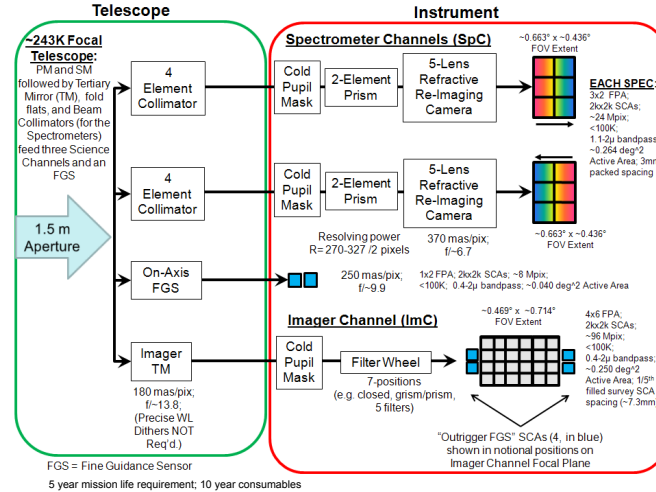
IDECS 2009

BAO / RSD / SNe / WL / Surveys



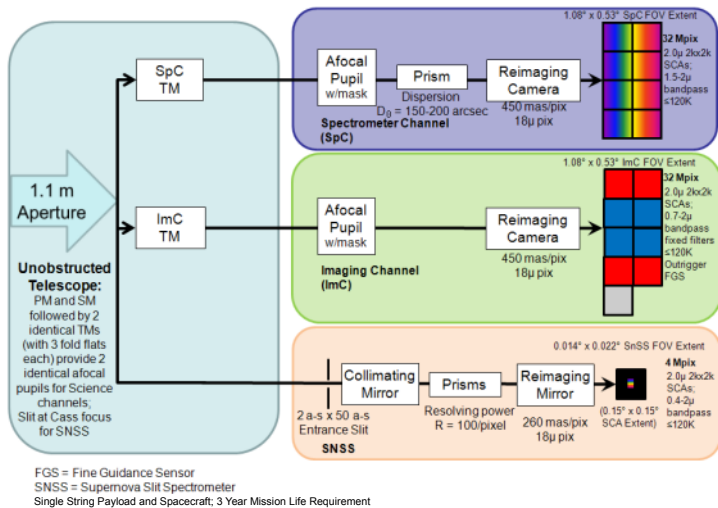
JDEM Omega 2009

Micro-lensing / BAO / RSD / SNe / WL / Surveys / GI Program



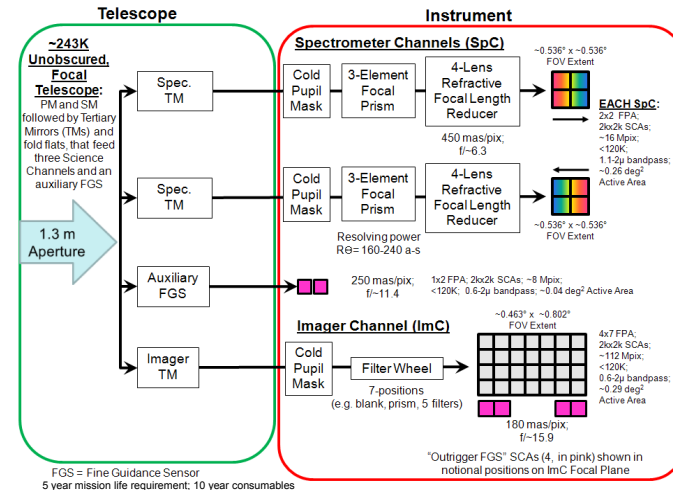
Probe 2010

BAO / RSD / SNe / WL photo-Z's



IDRM 2011

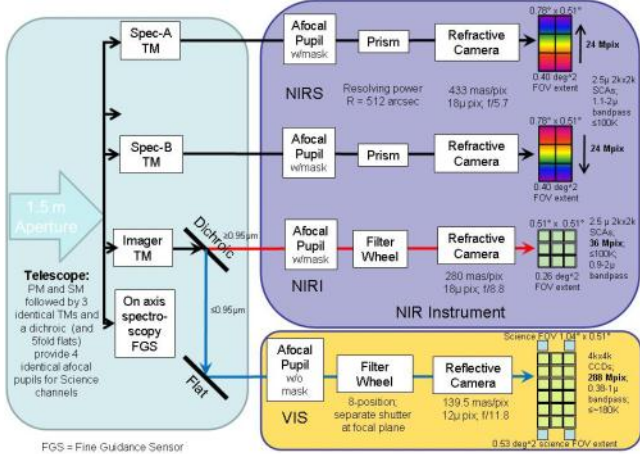
Micro-lensing / BAO / RSD / SNe / WL / Surveys / GI Program



JDEM - WFIRST DRM Evolution

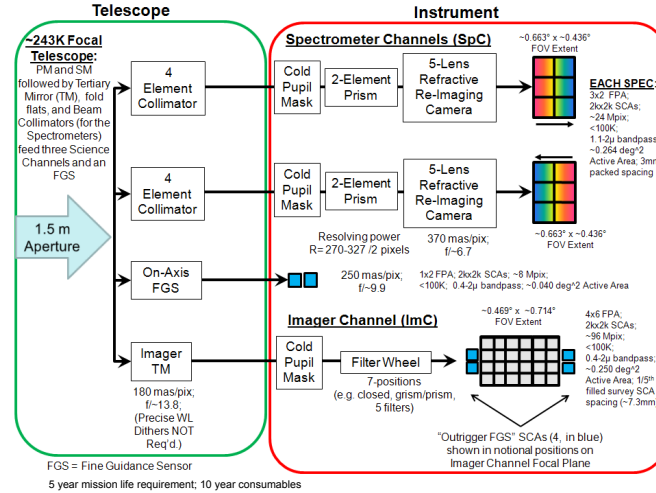
IDECS 2009

BAO / RSD / SNe / WL / Surveys



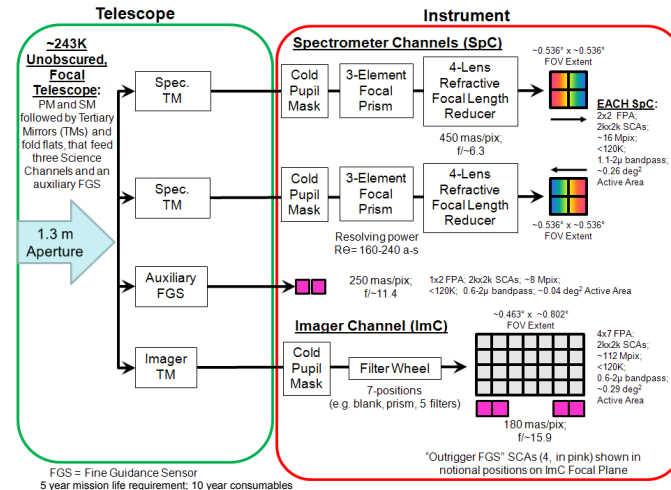
JDEM Omega 2009

Micro-lensing / BAO / RSD / SNe / WL / Surveys / GI Program



IDRM 2011

Micro-lensing / BAO / RSD / SNe / WL / Surveys / GI Program

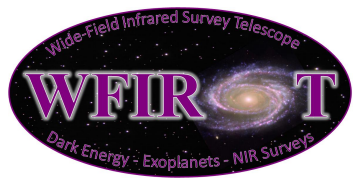


magnification

" / p

0.45

0.18



Independent Cost Estimate



- Performed by Aerospace Corp
- CATE = Cost And Technical Evaluation
- Input was Interim Design Reference Mission
- Aerospace cost estimate is within 7% of \$1.6B cost estimate from the Decadal Survey
- **"Project has presented a feasible technical design consistent with stated science goals"**

Requirements Flowdown

- Substantiation that WFIRST can achieve NWNH science
- Traces science requirements from top level objectives

WFIRST Science Objectives:

- 1) Complete the statistical census of planetary systems in the Galaxy, from habitable Earth-mass planets to free floating planets, including analogs to all of the planets in our Solar System except Mercury.
- 2) Determine the expansion history of the Universe and its growth of structure so as to test explanations of its apparent accelerating expansion including Dark Energy and modifications to Einstein's gravity.
- 3) Produce a deep map of the sky at NIR wavelengths, enabling new and fundamental discoveries ranging from mapping the Galactic plane to probing the reionization epoch by finding bright quasars at $z > 10$.

WFIRST Survey Capability Rqts

Exoplanet (Exp) Microlensing Survey

- Planet detection capability to ~ 0.1 Earth mass (M_{\oplus})
 - Detects ≥ 125 planets of $1 M_{\oplus}$ in 2 year orbits in a 500 day survey, with the masses of ≥ 90 of these planets being determined to better than 20% *
 - Detects ≥ 25 habitable zone[†] planets (0.5 to $10 M_{\oplus}$) in a 500 day survey *
 - Detects ≥ 30 free floating planets of $1 M_{\oplus}$ in a 500 day survey *
- * Assuming one such planet per star
[†] 0.72-2.0 AU, scaling with the square root of host star luminosity

Dark Energy Surveys

BAORSD Galaxy Redshift Survey

- $\geq 11,000$ deg² sky coverage per dedicated year ("WIDE" Survey mode)
- Goal of $\geq 2,700$ deg²/yr "DEEP" Survey acquired during the WL Survey
- A comoving density of galaxy redshifts at $z=2$ of 4.9×10^{-5} Mpc⁻³ (WIDE) or 2.1×10^{-4} Mpc⁻³ (DEEP). [The source density is higher at lower redshifts, peaking at $z=1$ at 2.2×10^{-4} Mpc⁻³ (WIDE) or 5.9×10^{-4} Mpc⁻³ (DEEP)]
- Redshift range $0.7 \leq z \leq 2$
- Redshift errors $\sigma_z \leq 0.001(1+z)$, equivalent to 300 km/s rms
- Misidentified lines \leq TBD% per source type, $\leq 10\%$ overall; contamination fractions known to 0.2% (TBR)

Supernova SNe-Ia Survey

WFIRST Data Set Rqts

Exoplanet Data Set Rqts

- Observe ≥ 2 square degrees in the Galactic Bulge at ≤ 15 minute sampling cadence
- S/N ≥ 100 for J-band magnitude ≤ 20.5 sources
- $\leq 0.3''$ imaging angular resolution
- Sample light curves with filter W149
- Monitor color with filter F087, 1 exposure every 12 hours
- Minimum continuous monitoring time span: ~ 60 days
- Separation of ≥ 4 years between first and last observing seasons

Dark Energy Data Sets

BAORSD Data Set Rqts

- **Spectrometer**
 - Slitless prism
 - Dispersion $R_{\text{eff}} = 195$ (TBR) - 240 arcsec
 - S/N ≥ 7 for $t_{\text{int}} = 300$ mas for H α emission line flux at $2.0 \mu\text{m}$ $\geq 1.5 \times 10^{-16}$ erg/cm²-s (DEEP) or 3.1×10^{-16} erg/cm²-s (WIDE)
 - Bandpass $1.116 \mu\text{m} \leq \lambda \leq 2.0 \mu\text{m}$
 - Pixel scale ≤ 450 mas
 - System PSF EE50% radius 400 mas at $2 \mu\text{m}$
 - ≥ 3 dispersion directions required, two nearly opposed
- **Imager (for redshift zero reference)**
 - S/N ≥ 10 for H α $\lambda 23.5$
 - Approximately equal time in filters F141 and F178

Supernova Data Set Rqts

- Minimum monitoring time-span for an individual

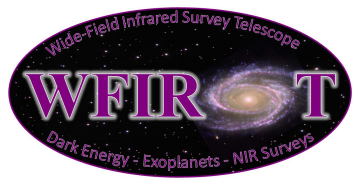
WFIRST IDRM Design/Operations Overview

Key WFIRST IDRM Observatory Design Parameters

- Off-axis focal telescope; 1.3m diameter telescope aperture
 - ≤ 240 K telescope optical surfaces
 - Bandpass 0.6 – $2.0 \mu\text{m}$
 - Pointing jitter ≤ 40 mas rms/axis
 - Coarse Pointing Accuracy $< \sim 3$ arcsec rms/axis
 - Fine (Relative/Revisit) Pointing Accuracy $< \sim 25$ mas rms/axis [TBR]
 - ACS telemetry downlinked for pointing history reconstruction
 - **Imager Channel (ImC): No re-imager; $\sim 180\text{K}$ Pupil Mask**
 - ImC Pupil Mask stop diameter: 1.275 m
 - ImC Effective Area: 0.811 m² (avg for all filters including QE and roll off)
 - 5 band parfocal filter set on wheel, driven by Exp, SNe, WL
 - R=75 (2-pix) parfocal, zero deviation prism + "dark" (TBD) position in same wheel
 - ImC R75 Slitless Prism Effective Area: 0.782 m²
 - ImC FPA: 4x7 HgCdTe 2x x 2x SCAs, $2.1 \mu\text{m}$, $\leq 120\text{K}$, 180 mas/pix
 - FOV (active area) = ~ 0.291 deg²; Bandpass 0.6 – $2.0 \mu\text{m}$
 - 4 Outrigger FGS SCAs mounted to ImC Focal Plane Assy (FPA)
 - WFE is diffraction limited at $1 \mu\text{m}$
 - TBD requirement on Intrinsic PSF ellipticity ... relate to knowledge reqt
 - **Slitless Spec Channels (SpCs): $\sim 180\text{K}$ Pupil Mask**
 - 2 oppositely dispersed SpCs provided, otherwise identical
 - Optical Path: pupil mask stop, focal prism, refractive focal length reducer
 - Bandpass $1.1-2.0 \mu\text{m}$; $R_{\text{eff}} = 160$ (TBR) - 210 arcsec
 - SpC Pupil Mask stop diameter: 1.27 m
 - SpC Effective Area: 0.731 m² (average including QE)
 - SpC FPA (1 of 2): 2x2 HgCdTe 2kx2k SCAs, $2.1 \mu\text{m}$, $\leq 120\text{K}$, 450 mas/pix
 - FOV (active area) = ~ 0.260 deg² (per SpC)
- Aux FGS: 2 SCAs: controls Pitch/Yaw when ImC prism is in use

Key WFIRST IDRM Operations Concept Parameters

- 5-year mission life, but consumables required for 10 yrs
- Science Field of Regard (FOR): 54° to 126° pitch off the Sun, 360° yaw
- Roll $\pm 10^\circ$; SNe observations inertially fixed for ~ 90 days for viewing near the ecliptic pole(s)
- Gimbaled antenna allows observing during downlinks
- Slew/settle times: ~ 16 s for dithers, ~ 38 s for $\sim 0.7^\circ$ slews

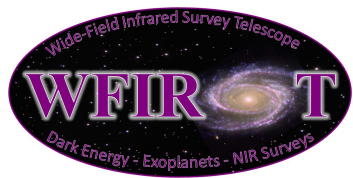


Workshare Assignments



- WFIRST Project resides in Exoplanet Exploration Program (ExEP) at JPL and is managed by GSFC
- WFIRST Project work is joint effort between GSFC and JPL
- GSFC responsibilities
 - Project management
 - System engineering
 - Instrument & spacecraft management
- JPL responsibilities
 - Telescope design & implementation
 - Participate in system engineering
 - Data center (IPAC)
- HQ program oversight
 - Program Executive: Lia LaPiana
 - Program Scientist: Rita Sambruna



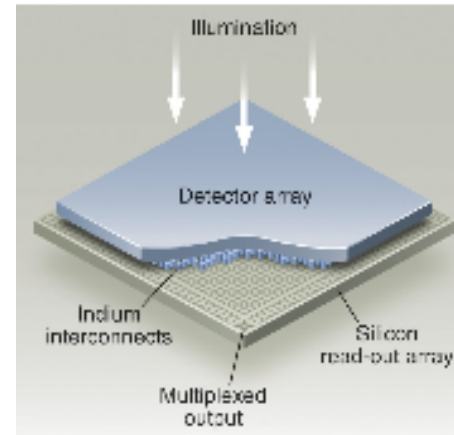


Detector Program



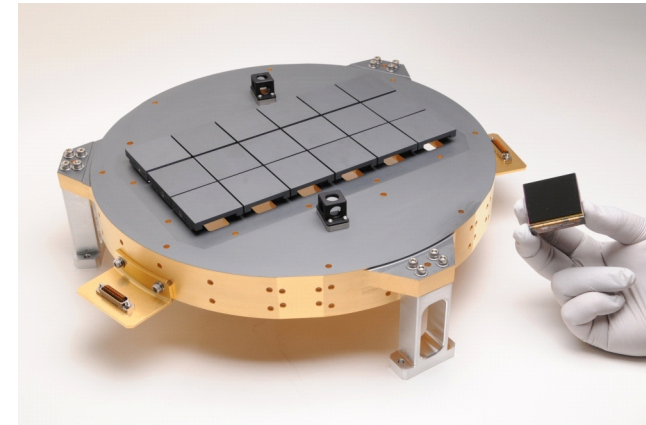
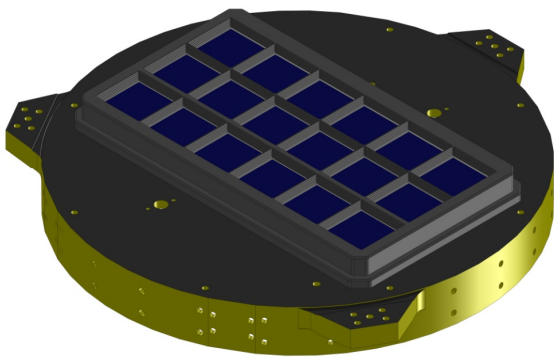
- H2RG detectors
 - H >> HAWAII = HgCdTe Astron. Wide Area IR Imager
 - 2 >> 2048 x 2048 pixels
 - R >> reference rows & columns to correct bias fluctuations
 - G >> guiding function, selectable window for guide star
- H1Rs used on HST. H2RGs developed first by SNAP team and then for JWST
- Goals of WFIRST program
 - Larger mosaics than JWST
 - Silicon carbide support structure
 - H4RG development

Sensor Chip Assembly



Detector Array EDU

- Development of 3x6 HgCdTe Engineering Development Unit detector array at GSFC



EDU Focal Plane Array

- Silicon carbide mounting of HgCdTe detectors is under development and will be space qualified with EDU

SDT with H4RG Array

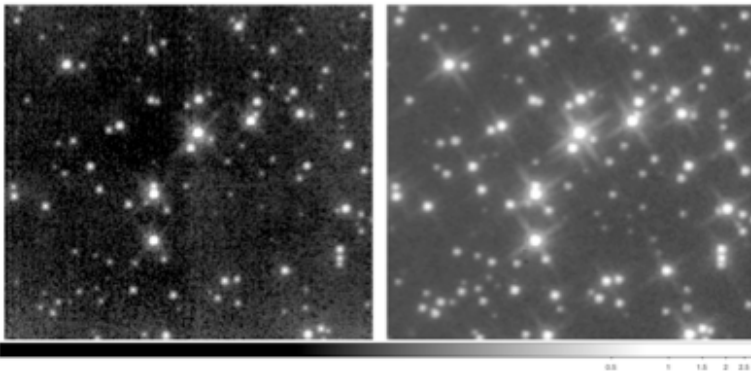


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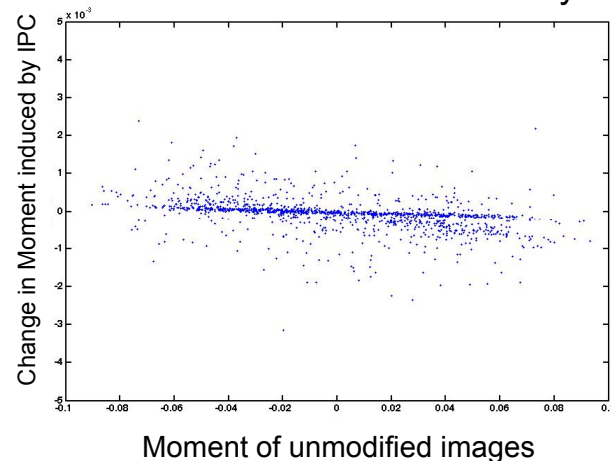
HgCdTe Performance Studies

- Potential issues with HgCdTe capabilities for WL shapes
 - Interpixel capacitance (IPC)
 - Persistence
 - Linearity & reciprocity
- Laboratory test program in place to assess issues (JPL, Caltech, Goddard, Teledyne, STScI, U Hawaii)
- Preliminary results are encouraging

Riess – HST WFC3 Linearity Study

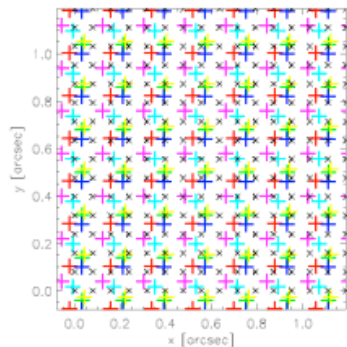


Marchant et al. – IPC Study

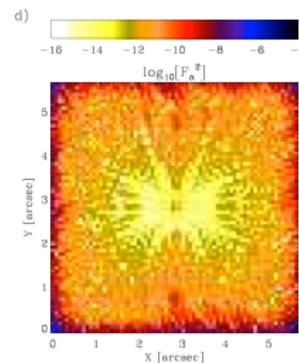


- Pixel scale study for WL at JP/Caltech (Rhodes, Hirata, Rowe)
 - Shapelet simulations, image combination software, dithering study
 - Results show that 0.18 "/pixel of WFIRST Imager is adequate for WL
 - WL image simulation software will be available to community via IPAC

pixel configuration

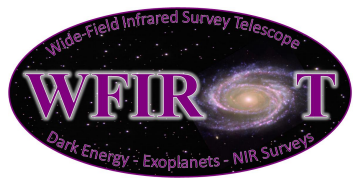


residuals



Rowe, Hirata & Rhodes 2011

- Sky tiling sims for BAO & SNe at GSFC (Kruk)
- Microlensing sims at Notre Dame/OSU (Bennett, Rhie, Gaudi)



WFIRST Schedule Forward



Mission formulation



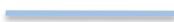
Technology work



NRC mid-decade rev.



Phase A



Phase B

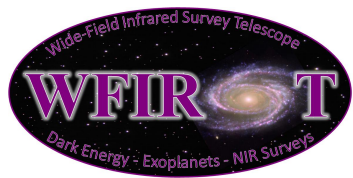


Phase C/D



Launch





Science Outreach



- Science calculators and estimators being deployed to the community through IPAC
- WFIRST booth developed and displayed at conferences
- IPAC Conference
- WFIRST "Meeting-In-A-Meeting" June 12-13 AAS in Anchorage
- Need for a brochure

