Overview

- ACS Lecture 1
  - Science drivers
  - Optics design
  - Detectors
  - Filters

- ACS Lecture 2
  - ACS thermal design
  - ACS science operations
  - Description of IDT science program
  - Science Discovery Efficiency
Design Goals

• Deep, survey imaging
  – I band optimized
  – Wide field
  – Discovery Efficiency (DW) = QE x Area
  – ACS Discovery Efficiency = 10 x WFPC2

• High resolution imaging
  – Near-UV optimized (200-400 nm)
  – Optimal sampling of PSF
  – High precision photometry
Design Goals

- **FUV Imaging**
  - Solar Blind Imaging
  - Low R spectroscopy
  - Backup FUV imaging

- **Stellar Coronograph**
  - high contrast imaging
  - high spatial resolution
ACS Science Team

Principal Investigator
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Ball Aerospace

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Wide Field Channel (WFC)
- Three mirror optical design
- Silver mirror coatings
- Optimized for I band imaging (NIR)
- 202” x 202” field of view
- 0.05”/pixel plate scale
- Two 2048 x 4096, 15 µm pixel CCDs
- Spectral response: 380 nm - 1050nm
WFC Optical Design
Mirror Coatings

WFC is IR optimized!

Degradation of witness sample (4 years)
HRC/SBC Specifications

- High Resolution Channel (HRC)
  - Three mirror design, MgF$_2$ on Al
  - 29" x 26" field of view
  - 0.026"/pixel plate scale
    - critical sampling of PSF at 500 nm
  - Spectral response: 200nm 1050 nm
  - 1024 x 1024 21 µm/pixel near-UV CCD
  - Stellar Coronograph mode
HRC/SBC Specifications

- Solar Blind Channel (SBC)
  - Two mirror design, MgF₂ on Al
  - 35" x 31" field of view
  - 0.032"/pixel plate scale
  - 1024 x 1024 CsI 25 µm/pixel MAMA
HRC/SBC Optical Design
Coronograph Design

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Coronograph Design

Occulting Masks

- 1.8” diameter spot
- 3.0” diameter spot

N.B. tilted optics
Coronograph Performance

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Post SM3B: HST Focal Plane
Imaging Performance

- WFC and HRC optics meet specification
  - WFC: 77% encircled energy in 0.25 arcsec
  - HRC: 87% encircled energy in 0.25 arcsec
- WFC elongated by 8%
- HRC/SBC elongated by 11%
ACS Optical Bench
ACS Optical Bench
Detector Requirements

- **CCD Requirements**
  - High QE (Discovery Efficiency goal of 10)
  - Large WFC format: 4096x4096 pixels
  - Overall WFC system noise goal: <4.6 e-RMS
  - Overall HRC system noise: <3.5 e-RMS
  - Foundry procurement for WFC
  - STIS 1kx1k with Steward NUV coating for HRC

- **SBC MAMA**: baseline STIS Flight spare
**Detector Architecture**

- **WFC CCDs fabricated by SITe**
  - thinned, backside-illuminated
    - Multi-phase pinned (MPP)
      - low dark current
      - radiation protection

- **Backside passivation process**
  - WFC: SITe processed
    - SITe ion implant + AR coating
  - HRC: SITe + UA processed
    - Catalytic process + AR coating
WFC CCD Quantum Efficiency

Instrument throughput vs. Wavelength (nm)

- WFPC2
- WFC

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HRC Fringing

Issue for:
- Grism
- IR ramp
WFC Full Well

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## WFC CCD Performance

<table>
<thead>
<tr>
<th>Device</th>
<th>Lot</th>
<th>CTE Parallel</th>
<th>CTE Serial</th>
<th>R_n (e^-)</th>
<th>QE 400 nm</th>
<th>QE 600 nm</th>
<th>QE 800 nm</th>
<th>Dark 400 nm</th>
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<td>0.999999</td>
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<td>74%</td>
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Charge Transfer Efficiency

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Radiation Damage

- Minimize parallel readouts

- Mini-channel
  - ~5k-10ke⁻ deep channel inside buried channel
  - reduces trap cross-section at low signal levels
Long wavelength halo

CCD Package Cross-section

- Backside illuminated, thinned CCD (~15 µm)
- Al metal layer reflects long-λ photons
- Soda glass header 2000 µm
- Header metalization

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Long wavelength halo

Measured flux in the halo

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<th>λ (nm)</th>
<th>%</th>
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<td>780</td>
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<td>900</td>
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<td>1030</td>
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HRC CCD Quantum Efficiency

Instrument throughput vs. Wavelength (nm)

- WFPC2
- HRC

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# HRC CCD Performance

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<td>@250 nm</td>
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<td>@400 nm</td>
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<td>@800 nm</td>
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<tr>
<td>Amp. B</td>
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<tr>
<td>Amp. C</td>
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<tr>
<td>Amp. D</td>
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<table>
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<tr>
<th>Full Well</th>
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<tr>
<td>150000 e⁻ RMS</td>
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<table>
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<th>Dark Current</th>
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<td>21 e⁻/pixel/hr</td>
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<table>
<thead>
<tr>
<th>CTE</th>
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<tbody>
<tr>
<td>Parallel CTE</td>
</tr>
<tr>
<td>Serial CTE</td>
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</table>
HRC CCD Cosmetics

- 250 nm flat field

- 800 nm flat field
CCD Packaging

- WFC dewar employs a double shell
  - thermal goal of CCD temperature = -85°C
  - internal surfaces anti-reflection coated

- HRC dewar employs a single shell design
  - thermal goal of CCD temperature = -83°C
  - internal surfaces anti-reflection coated

- Outer dewar windows are warm
  - No degradation of UV/Visible performance
WFC CCD Dewar

CCD header assembly

Inner dewar shell

WFC Dewar Schematic
Selected STIS flight spare

- CsI photocathode
- STIS MAMA performance
  - except dark = $10^{-4}$ c/s/pixel
  - Removed time-tag
  - 1024x1024 format only
Filter Design Goals

- **Broadband filters**
  - link to WFPC2 photometric system
  - link to ground-based surveys
  - optimize for deep imaging programs

- **Narrowband filters**
  - core filter set with full WFC field of view
  - moderate field of view narrowband imaging at all λ

- **Slitless spectroscopy**
  - redshifts for deep imaging surveys

- **Polarimetry**
  - optimized for visible/NUV
Broadband Filters

- Deep imaging: I
  - Sloane Digital Sky Survey (SDSS)
**Broadband Filters**

- **Deep imaging: I**
  - Sloane Digital Sky Survey (SDSS)

- **Deep Imaging: II**
  - Wide-Y, I
Deep Imaging Filters
Broadband Filters

- Deep imaging: I
  - Sloane Digital Sky Survey (SDSS)
- Deep Imaging: II
  - Wide-V, I
- Photometry
  - B, V, R & I
BVRI Filter Set

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Transmittance

Wavelength (nm)

F814W
F625W
F555W
F435W

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- Broadband Filters (FOV)
  - Deep imaging: I
    - Sloane Digital Sky Survey (SDSS)
  - Deep Imaging: II
    - Wide-V, I
  - Photometry
    - B, V, R & I
- Near-UV Imaging (FOV)
  - High throughput + low red leak
  - F220W, F250W, HRC-U, & WFC U
Near-UV Filter Set
Narrowband Filters

- Ramp Filters
  - FOV ~40”x70”
  - 2% narrowband imaging
    - [OII]: 371 nm - 482 nm (HRC: 371 nm - 405 nm)
    - [OIII]: 482 nm - 627 nm (HRC: 482 nm - 527 nm)
    - Hα: 627 nm - 816 nm (HRC: 627 nm - 685 nm)
    - I band: 816 nm - 1061 nm
  - 9% medium bandpass filter
    - Medium Band - 9% 381 nm - 1071 nm
      (HRC: 381 nm - 537 nm, 757 nm - 1071 nm)
Ramp Filters

Diagram shows looking through filter towards detector

Angular scales are approximate since field has non-linear distortion when projected on filters or detector

WFC format

Min. wavelength

Max. wavelength

Filter wheel rotation

HRC format

WFC 100 arcsec

HRC 25 arcsec

25 mm on filter

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Narrowband Filters

- WFC (full 202”x202” FOV)
  - Hα: 1% bandpass
  - [Oiii]: 1% bandpass
  - [Nii]: 0.5% bandpass
  - Continuum: 10% bandpass

- HRC
  - NeV: 2% bandpass
  - Methane: 2% bandpass
Dispersers/Polarizers

- **Gris:**
  - $R \approx 100$
  - WFC & HRC

- **NUV Prism:**
  - $R \approx 100$

- **FUV Prisms**
  - LiF: $R \approx 100$
  - CaF$_2$: $R \approx 100$
Polarizers

• 3 polarization angles
  – $0^\circ$, $60^\circ$, $120^\circ$

• UV (HRC)
  – F344N, F435W, F330W,
  – F250W, F220W

• Visible (WFC)
  – F475W, F555W, F625W,
  – F606W, F658N, F502N,
  – F550M
# Filter Summary

<table>
<thead>
<tr>
<th>#</th>
<th>Filter Name</th>
<th>Filter Description</th>
<th>Camera</th>
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<td>F555W</td>
<td>Johnson V</td>
<td>● ● ●</td>
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<td>2</td>
<td>F775W</td>
<td>SDSS i</td>
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<td>F625W</td>
<td>SDSS r</td>
<td>● ● ●</td>
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<td>4</td>
<td>F658N</td>
<td>Hα</td>
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<td>F850LP</td>
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<td>F502N</td>
<td>[OIII]</td>
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<td>Clear</td>
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<td>[OIII] Ramp</td>
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- WFC
- HRC

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SBC Filter Wheel

Aperture stops for MAMA bright object protection strategy

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SBC Filter Set
WFC Throughput

Throughput (%)

Wavelength (nm)

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HRC Throughput

Throughput (%)

Wavelength (nm)

- WFPC2
- STIS
- HRC

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SBC Throughput

- Science driver is Dark rate

Throughput (%)

Wavelength (nm)

STIS
ACS-SBC

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