STScI WFIRST SCIENCE CENTER ACTIVITIES

Roeland van der Marel

STScI WFIRST Mission Head

February 29, 2016

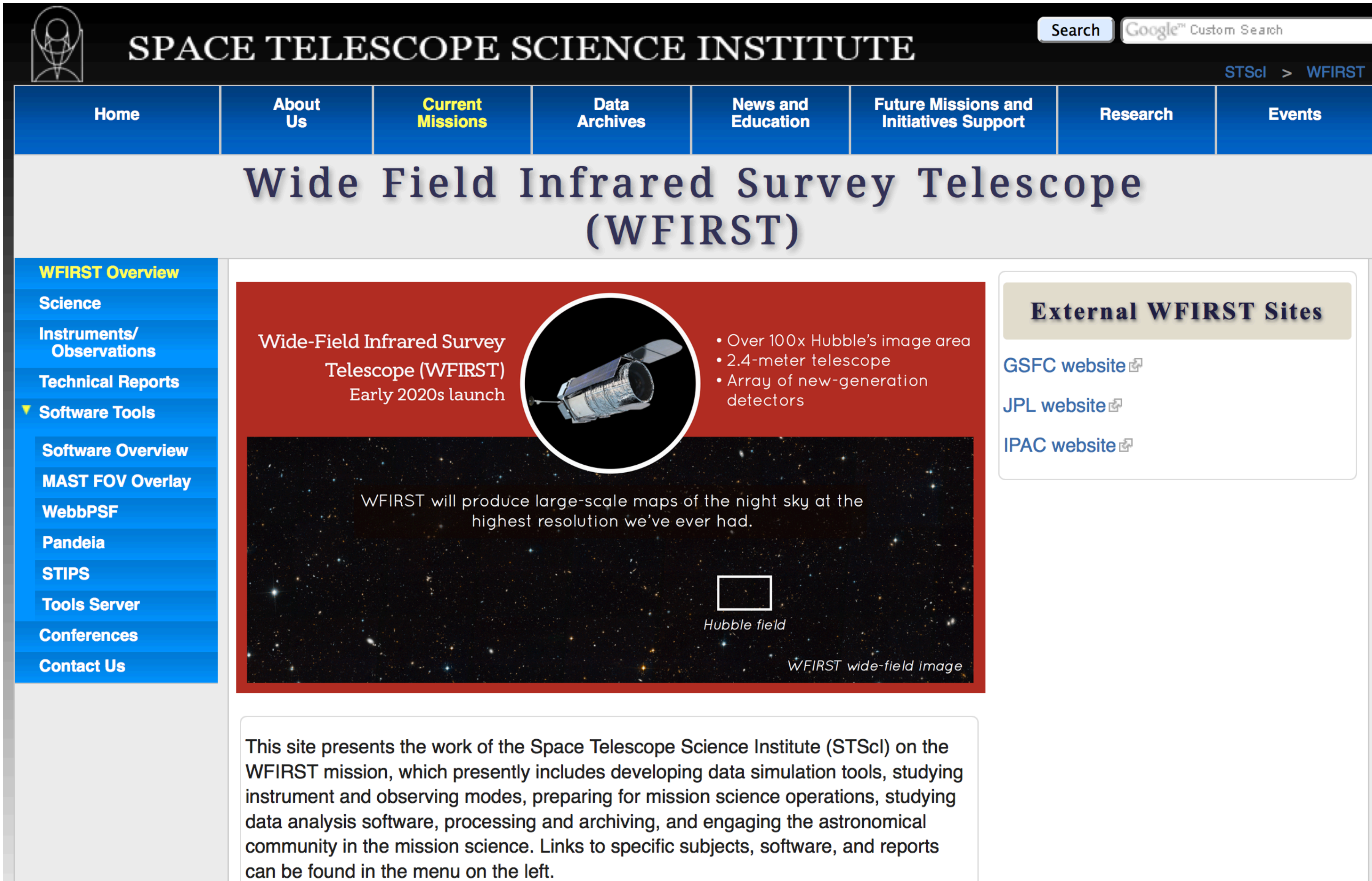
Pre-formulation Work

- WFIRST Moved into Formulation (Phase A) on Feb 17, 2016
- STScI has been funded since 2014, jointly with IPAC, for science center studies
- Specific topics addressed at STScI
  - Creation of Simulation Tools
    - Several Python-based multimission tools adapted from JWST
    - Emphasis on telescope, instruments, detectors, …
  - Technical Reports
    - select technical and science operations topics
  - Community Engagement

WFIRST
WIDE-FIELD INFRARED SURVEY TELESCOPE
DARK ENERGY • EXOPLANETS • ASTROPHYSICS

STScI WFIRST Website

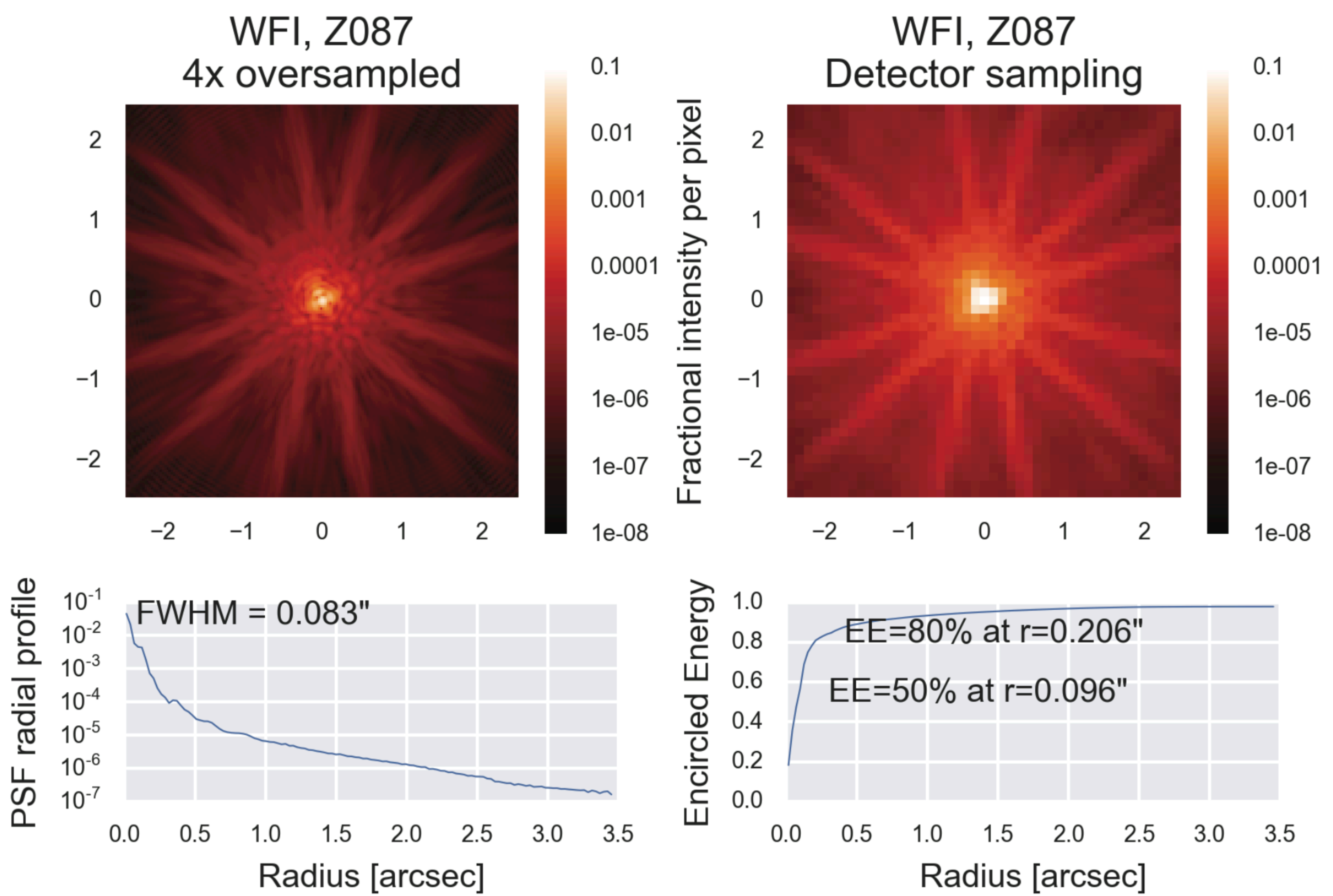
http://www.stsci.edu/wfirst



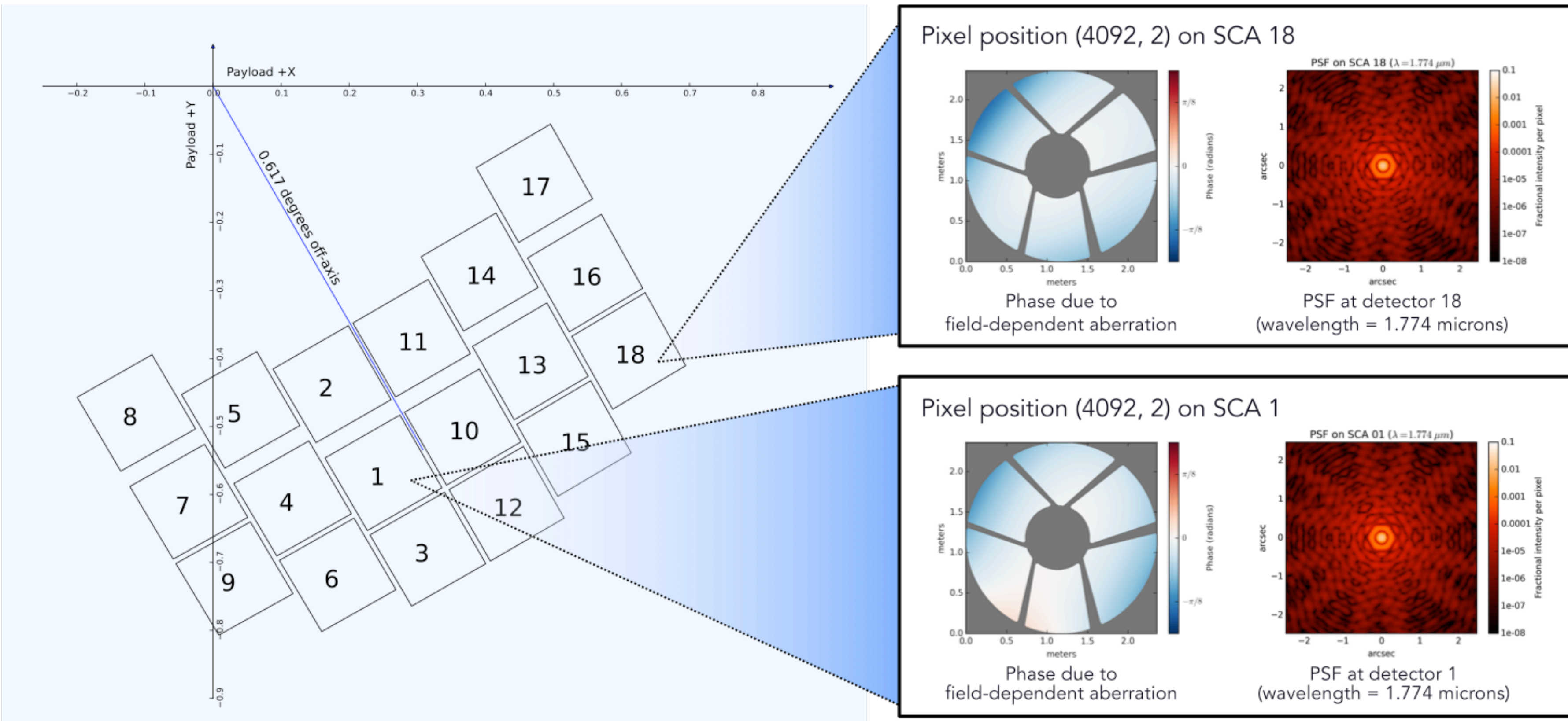
WebbPSF

- Calculates field and wavelength/filter dependent PSFs for use in other tools and for science planning (Perrin, Long)
- Open source, ITAR-free, flexible, and well-documented Python code
- Uses known pupil geometry, WFE models, and instrument properties
- Status:
  - WFI functionality released (beta version)
  - Work on extensions to other WFIRST modes ongoing

WebbPSF Examples



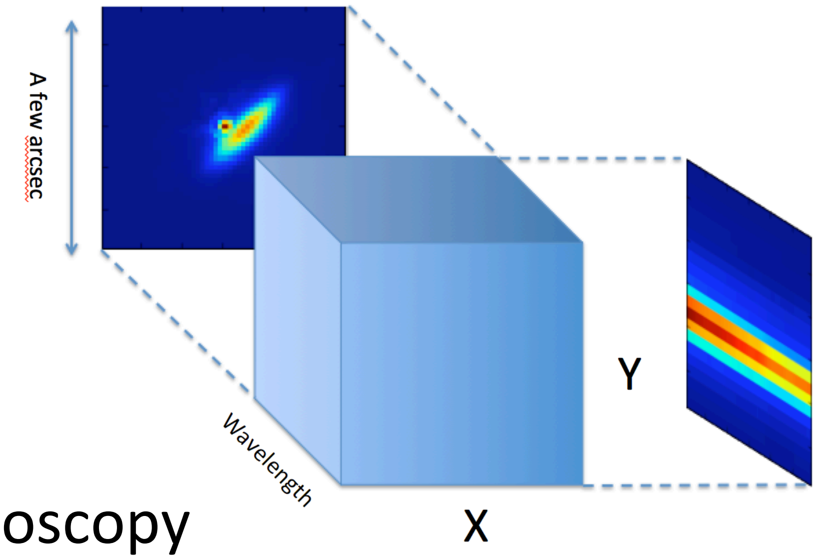
WebbPSF Field Dependence



WFIRST focal plane for wide-field imaging

Pandeia

- Detailed "scene" creation for broad science cases (Pontoppidan, Pickering, Laider et al. Pandeia Team)
  - extra-galactic, galactic, stellar, etc.
- Full three-dimensional model
  - two spatial, one wavelength
- Detailed detector models
- Focus on calculating accurate exposure times (ETC) and signal-to-noise ratios
- Supports both imaging and spectroscopy
- Status:
  - WFI functionality released through web interface (beta version)
  - IFU functionality completed
  - Work on extensions to other WFIRST modes ongoing
  - Release of source code planned for the future



Pandeia Imaging Interface

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In [3]:
```
g = WFIRST_gui()
g.display
```

Source type: point

Source flux: 10 ujy at 1 microns

SED type: extragalactic | Mrk 33 (Wolf-Rayet Galaxy) | Redshift: 0.25

Instrument: Imager | Filter: z087 | Readmode: rapid | Sub-array: full

Groups: 10 | Integrations: 1 | Exposures: 1

Aperture radius (arcsec): 0.3 | Overlay ☑

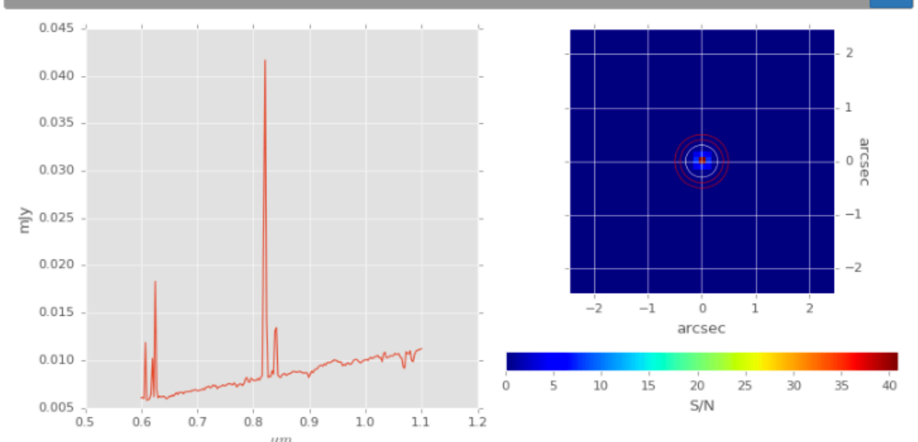
Background annulus radii (arcsec): inner 0.4 | outer 0.5

Calculate

Extracted S/N: 19.53 **Extracted Flux (e-/sec):** 41.10 **Exposure Time (sec):** 106.30

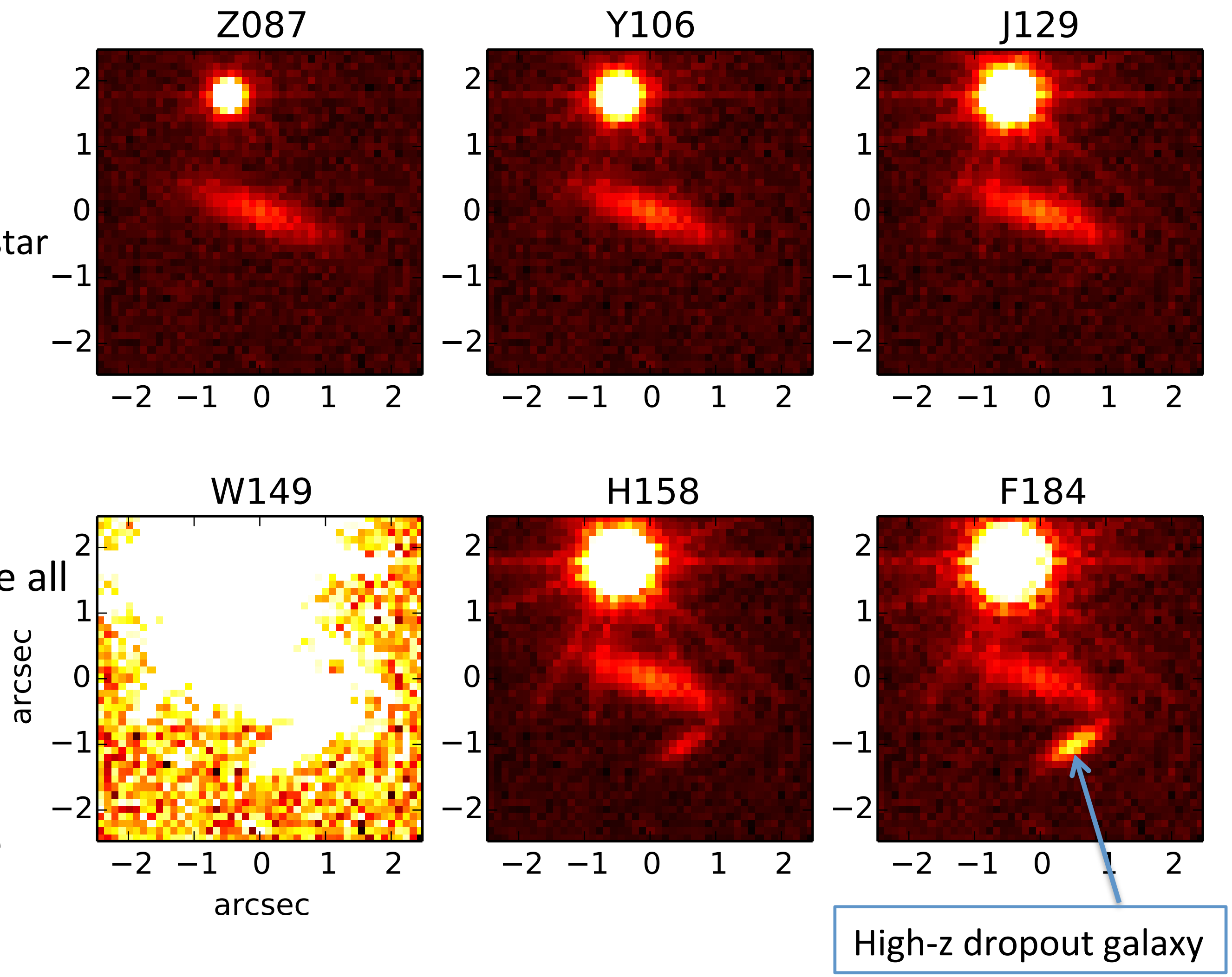
1D Plot: Input Source Flux (mJy) | 2D Image: S/N

Figure 6

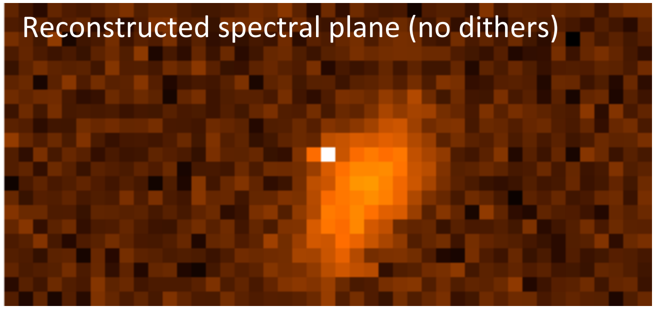


Pandeia (3b): WFIRST WFI Example

- 1040 second ramp
- Sources include
  - a bright, saturating star ($AB_{1.5micron}$= 17.15)
  - a low-z galaxy ($AB_{1.5micron}$ = 21.78)
  - a high-z galaxy ($AB_{1.5micron}$= 24.29)
- The image stretches are all set to the same detector electron rate
- This is particularly noticeable for the wide W149 filter.

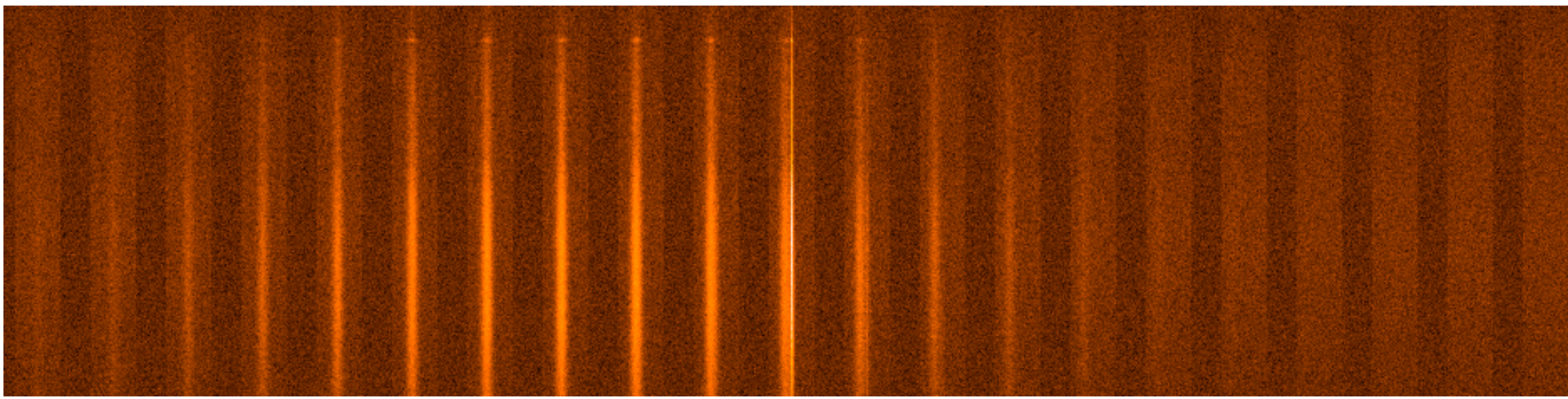


Pandeia IFU Example



Example of a Pandeia/WFIRST calculation for one of the potential IFU designs (designs can be revised in seconds).

- Galaxy + point source (point source normalized to 2.2 muJy at 0.556 micron).
- 0.15” pixels, 1 pixel per slice, 3” slice length.

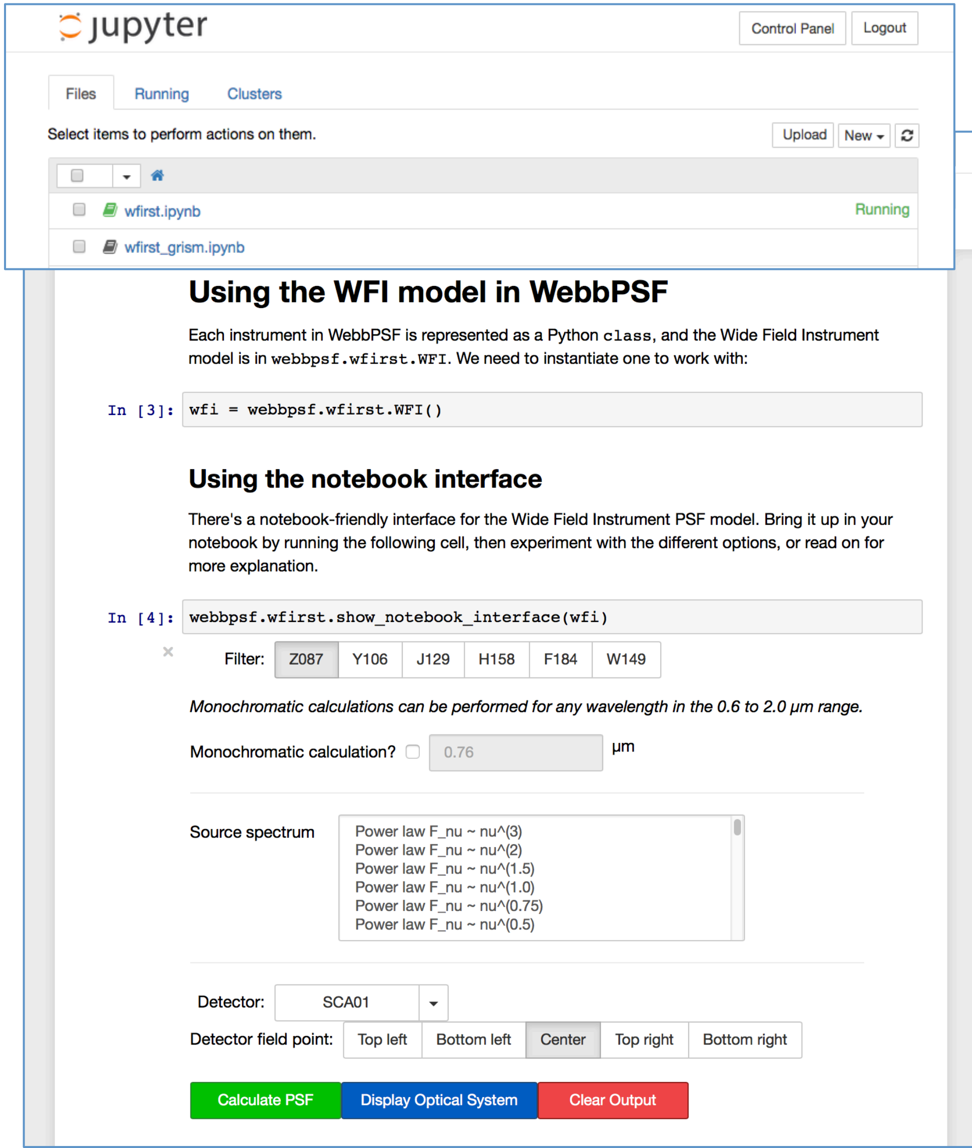


- Cross validated against independent IFU simulator software developed by D. Law (STScI) and D. Rubin (Perlmutter SIT)

WFIRST Tools Server (JupyterHub)

WebbPSF and Pandeia available to the community via web server

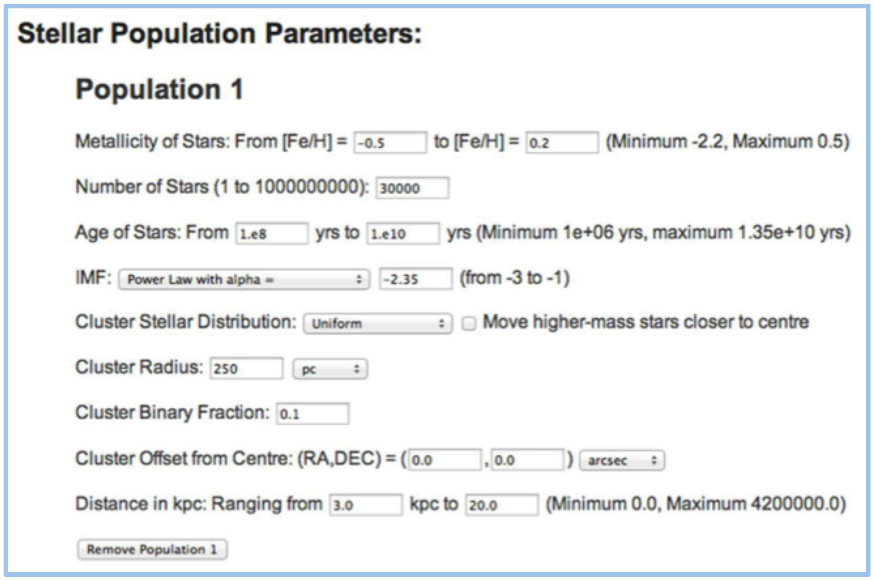
- Python + Web application based on Jupyter (IPython ; jupyter.org)
- Lets WFIRST-affiliated users run calculations with Pandeia and WebbPSF, without any software install or setup themselves
- Multi-user access; STScI manages server setup, software updates, grants access (through github accounts)
- Code samples and GUI interfaces provided as notebooks that combine documentation with code
- Users can upload/download calculation notebooks and results



STIPS (Space Telescope Image Product Simulator)

- Simulate larger-scale complex astronomical scenes (York, Kalirai, Casertano et al.)
- Provides users the flexibility in choosing a range of populations to mimic their science goals (e.g., SFHs, abundances, distances, spatial distributions)
- Status:
  - Initial focus on WFI imaging of galactic and stellar applications
  - First beta-release through a web interface planned for Spring 2016
  - Work on extensions to other WFIRST modes and extragalactic scenes ongoing
  - Release of source code planned for the future

STIPS Example


Stellar Population Parameters:

Population 1

Metallicity of Stars: From [Fe/H] = -0.5 to [Fe/H] = 0.2 (Minimum -2.2, Maximum 0.5)

Number of Stars (1 to 1000000000): 30000

Age of Stars: From 1.e8 yrs to 1.e10 yrs (Minimum 1e+06 yrs, maximum 1.35e+10 yrs)

IMF: Power Law with alpha = -2.35 (from -3 to -1)

Cluster Stellar Distribution: Uniform ☐ Move higher-mass stars closer to centre

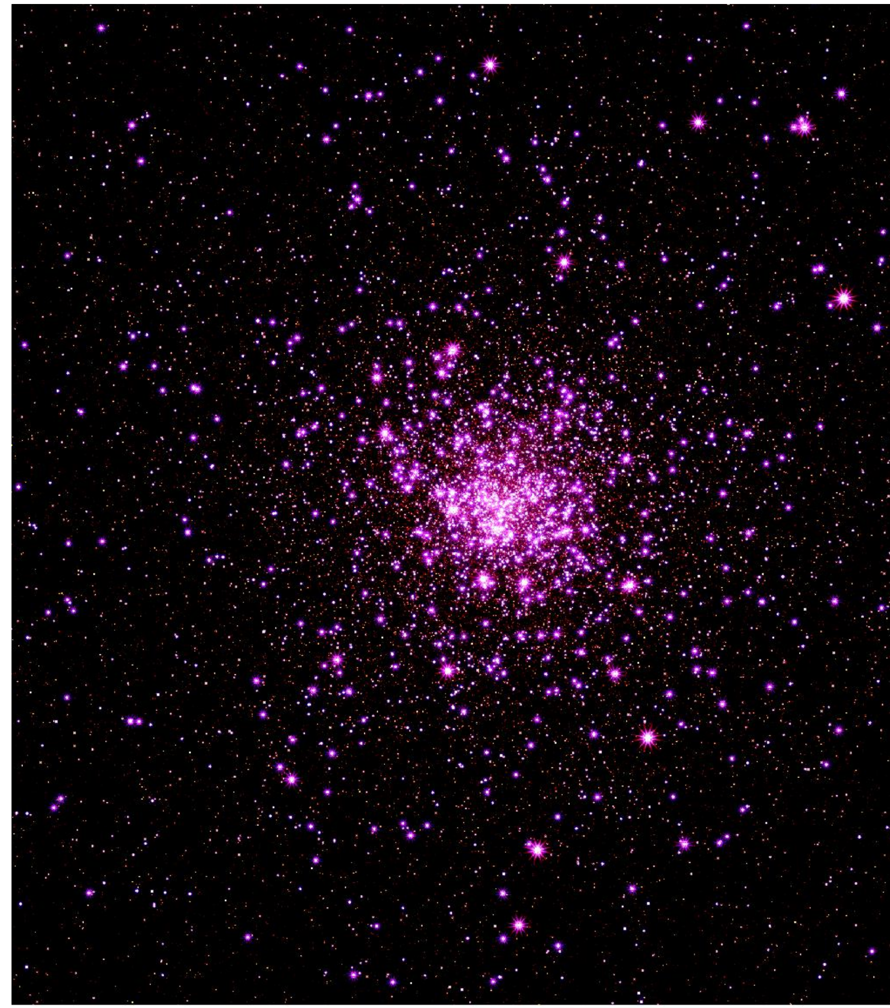
Cluster Radius: 250 pc

Cluster Binary Fraction: 0.1

Cluster Offset from Centre: (RA,DEC) = (0.0 , 0.0) arcsec

Distance in kpc: Ranging from 3.0 kpc to 20.0 (Minimum 0.0, Maximum 4200000.0)

Remove Population 1



Simulated Star cluster with user-specified properties

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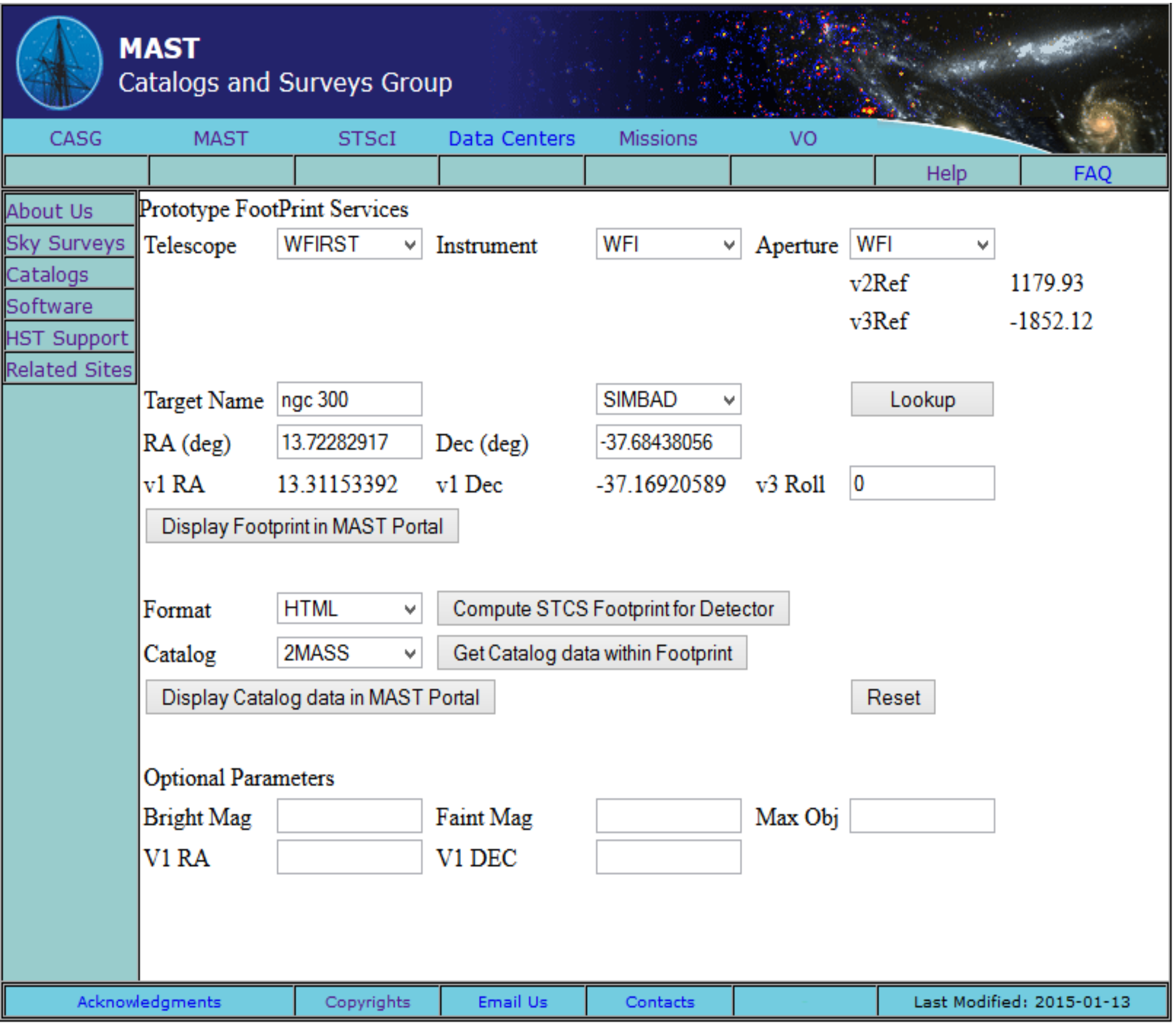
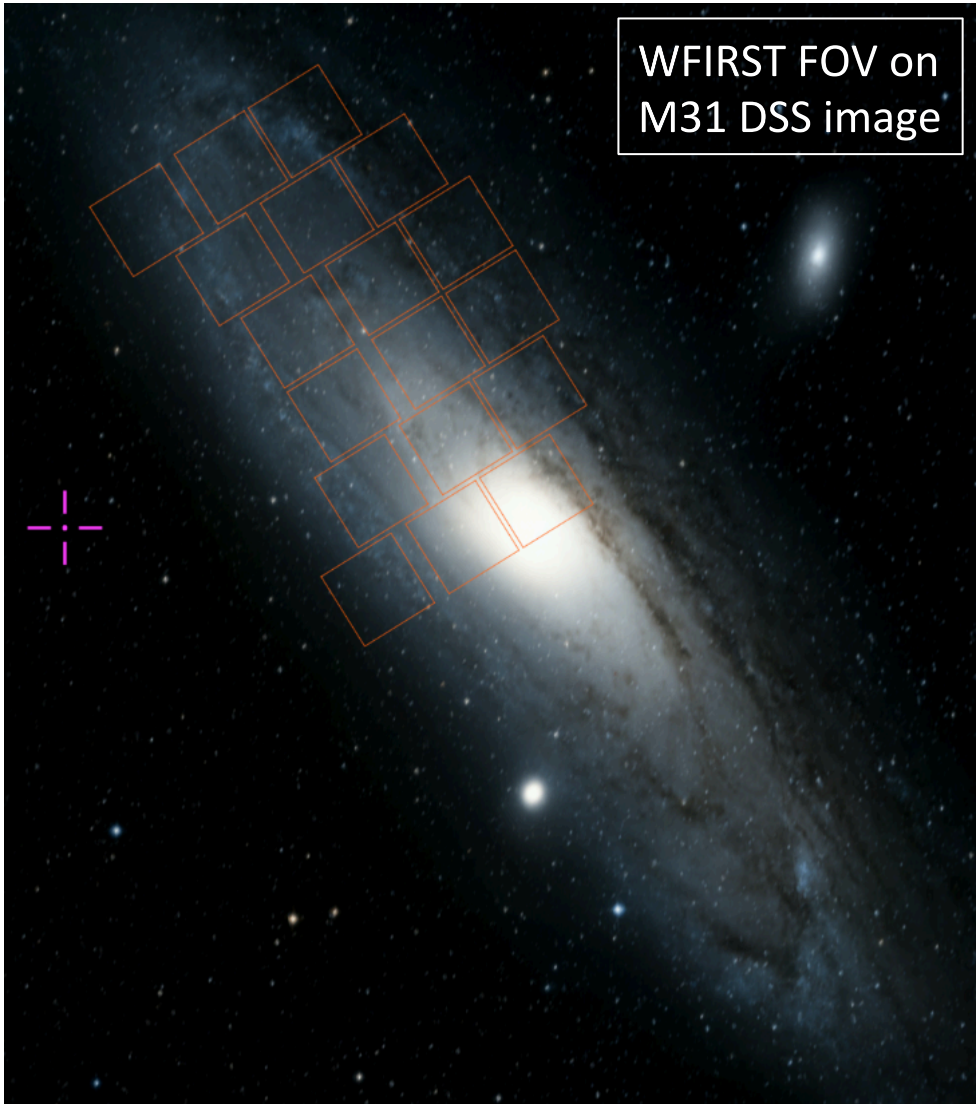
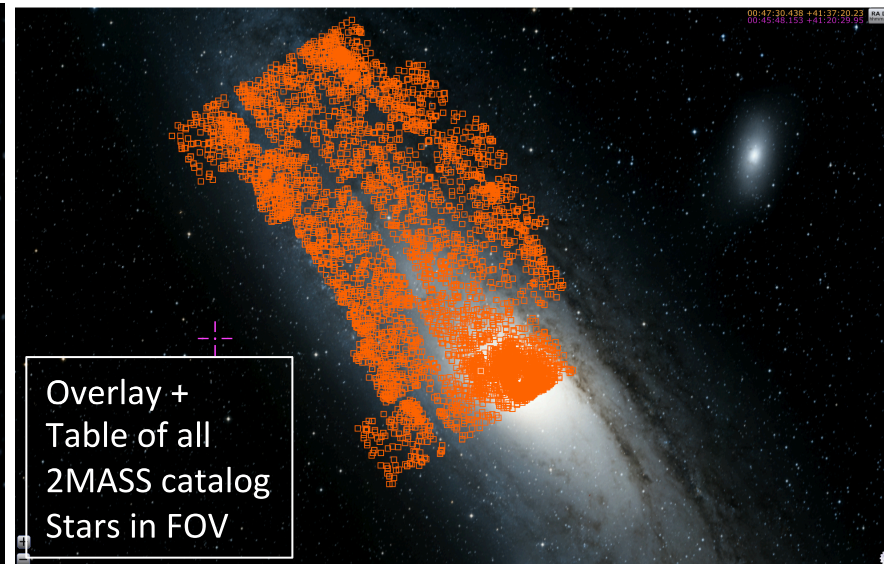
MAST Field of View Tool – Web Interface



- Functionality (McLean):
  - web-service in Mikulski Archive for Space Telescopes (MAST)
  - display WFIRST footprint
  - return catalog objects within specified detectors(s)
- Coordinates:
  - Name resolver; or
  - Manual input
- Display with MAST portal
  - Footprints (on DSS, SDSS, or GALEX sky image)
  - Catalog data
- Catalogs
  - GSC & 2MASS (WISE planned)

MAST Field of View Tool - Andromeda Galaxy Example





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Objects found : 5094 , Footprint: TELE= WFIRST INST=WFI APER=WFI RA=11.61847 DEC=41.24229 PA=155 CAT=2MASS,OK

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553129599	10.963294	41.69656	0.12	0.11	0	00435119+4141476	15.998	0.084	0.084	15.4	15.38	0.096	0.096	12.1	15.457	0.155	0.155	7.1	AAB
553129626	10.983395	41.689308	0.23	0.22	113	00435601+4141215	16.869	0.175	0.175	6.9	16.12	0.181	0.181	6.1	15.633	0.19	0.19	6	CCC
553129627	10.948221	41.689171	0.23	0.19	175	00434757+4141210	16.895	-999	-999	-999	15.959	0.175	0.175	7.1	15.499	0.161	0.161	6.8	UCC
553129630	10.99024	41.688473	0.22	0.19	101	00435765+4141185	16.496	-999	-999	-999	15.826	0.163	0.163	8	15.529	0.174	0.174	6.6	UCC
553129639	10.996409	41.685894	0.23	0.19	12	00435913+4141092	16.957	0.184	0.184	6.4	16.068	0.17	0.17	6.4	15.608	0.182	0.182	6.1	CCC
553129642	10.991994	41.685108	0.08	0.08	73	00435807+4141063	15.953	0.081	0.082	16.1	15.252	0.083	0.084	13.6	15.18	0.132	0.132	9.1	AAB
553129655	10.997445	41.680286	0.12	0.11	92	00435938+4140490	16.092	0.091	0.092	14.2	15.351	0.092	0.092	12.4	15.266	0.137	0.138	8.4	AAB
553129658	10.967919	41.679413	0.11	0.11	90	00435230+4140458	16.021	0.083	0.083	15.1	15.236	0.085	0.086	13.8	15.269	0.129	0.129	8.4	AAB
553129666	10.986007	41.67712	0.21	0.2	91	00435664+4140376	16.471	0.114	0.115	10	15.76	0.125	0.125	8.5	15.585	0.19	0.19	6.3	BBC
553129689	10.941747	41.670502	0.18	0.18	50	00434601+4140138	16.742	0.158	0.158	7.8	15.741	-999	-999	-999	15.448	-999	-999	-999	CUU
553129690	11.021554	41.670292	0.16	0.14	4	00440517+4140130	16.474	0.123	0.123	10	15.654	0.13	0.131	9.4	15.227	-999	-999	-999	BBU
553129692	10.959821	41.67001	0.06	0.06	90	00435035+4140120	14.379	0.032	0.034	68.5	14.144	0.036	0.037	37.7	14.027	0.048	0.049	26.3	AAA
553129693	11.035484	41.669647	0.06	0.06	73	00440851+4140107	15.799	0.057	0.058	18.5	14.957	0.076	0.076	17.8	14.61	0.077	0.078	15.4	AAA
553129698	11.022804	41.667706	0.06	0.06	90	00440547+4140037	14.093	0.025	0.028	89.2	13.703	0.031	0.032	56.6	13.702	0.034	0.035	35.5	AAA
553129705	11.033071	41.665771	0.06	0.06	73	00440793+4139567	15.553	0.064	0.065	23.2	14.67	0.053	0.054	23.2	14.434	0.064	0.065	18.1	AAA
553129712	10.97634	41.664227	0.22	0.19	165	00435432+4139512	16.865	0.175	0.175	6.9	15.966	0.163	0.163	7	15.582	0.176	0.176	6.3	CCC
553129721	11.027314	41.662365	0.18	0.16	161	00440655+4139445	16.5	0.114	0.115	9.7	15.684	0.125	0.125	9.1	15.322	0.137	0.138	8	BBB
553129726	10.953119	41.661015	0.06	0.06	90	00434874+4139396	13.458	0.024	0.027	160	13.002	0.023	0.024	107.9	12.921	0.026	0.027	73	AAA
553129727	10.933112	41.660957	0.24	0.22	134	00434394+4139394	16.647	-999	-999	-999	15.833	0.168	0.168	8	15.627	0.189	0.189	6	UCC
553129728	10.996101	41.660782	0.14	0.13	9	00435906+4139388	16.169	0.116	0.117	13.2	15.418	0.115	0.115	11.7	15.277	0.14	0.141	8.3	BBB

objID	rd_flg	bl_flg	cc_flg	ndet	prox	pxpa	pxcntr	gal_contam	mp_flg	hemis	date	scan	glon	glat	x_scan	jdate
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553129630	022	011	000	000505	13	159	553129642	0	0	n	1998-12-04	42	121.435	-21.161	78.2	2451151.64
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553129642	222	111	000	362606	12.2	77	553129639	0	0	n	1998-12-04	42	121.436	-21.165	73.5	2451151.64
553129655	222	111	000	160506	20.4	352	553129639	0	0	n	1998-12-04	42	121.441	-21.17	58.8	2451151.64
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553129727	022	011	000	000506	19.6	257	1287684683	0	0	n	1998-12-04	42	121.389	-21.188	231.9	2451151.64
553129728	222	222	ccc	463406	3.9	138	553129732	0	0	n	1998-12-04	42	121.439	-21.189	62.5	2451151.64

1 2 3 4 5 6 7 8 9 10 ... >>

2015/2016 STScI Technical Reports

- Scheduling
  - Prototype scheduling of WFIRST programs (Giuliano et al.)
- Guiding
  - Availability of suitable guide stars for WFI imaging (Nelan et al.)
  - Availability of suitable guide stars for WFI grism w/ aux guider (Nelan et al.)
- WFI Grism (➔ Casertano talk)
  - Data reduction software (Mackenty et al.)
  - Observing mode, calibration, etc. (Casertano et al.)
  - Pointing reconstruction from dispersed images (Dixon)
- Microlensing
  - Saturation and Persistence effects (Sahu)
- Coronagraph (➔ Pueyo talk)
  - Lessons from HST and JWST coronagraphs (Debes et al.)
  - Data post-processing (Ygouf et al. 2015; Ygouf et al. 2016)
  - Wavefront control (Mazoyer et al.)

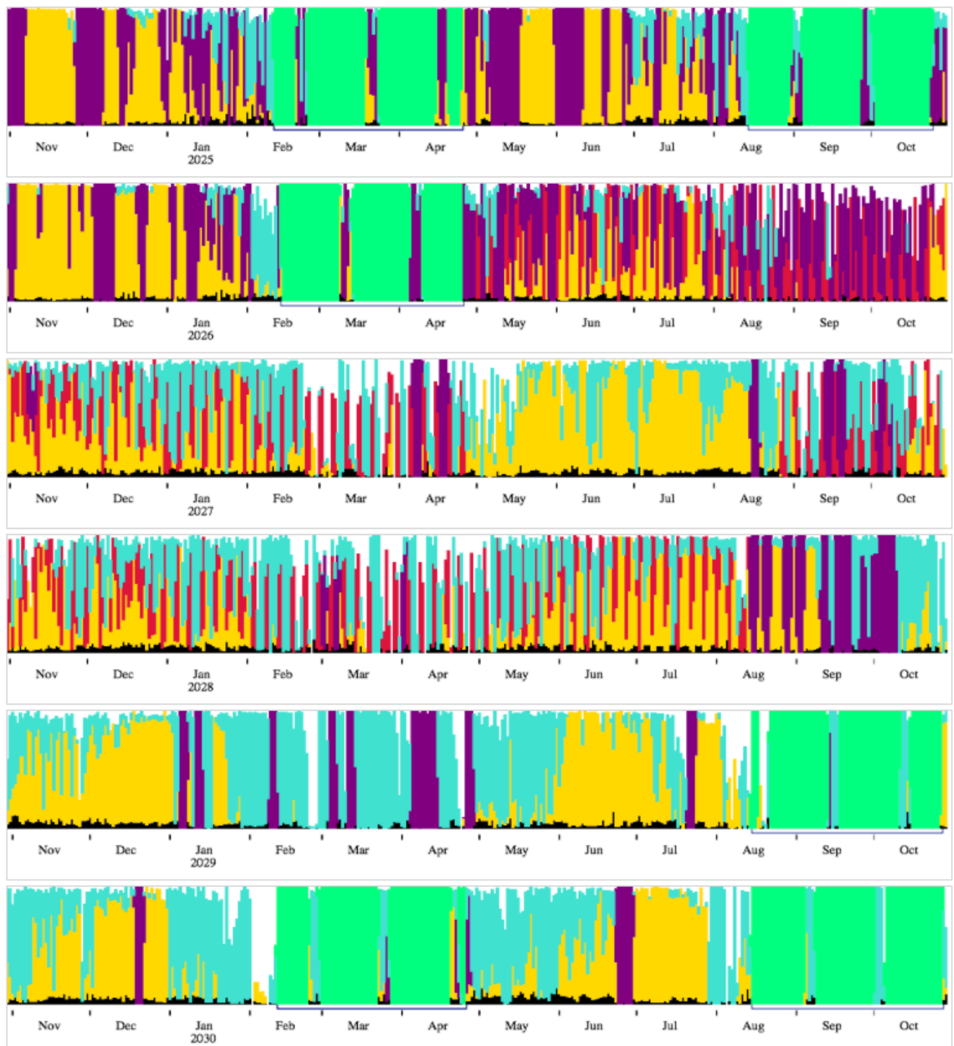
Blue: To be released in coming weeks

Note: Studies of many other topics ongoing (➔ e.g. IFU, Law talk)

Scheduling Example

KEY:
Slew
HLS
Supernova
Coronography
GO
Microlensing

Time used by each program in schedule (counted in seconds)



Year 1

Year 6

Community Engagement

STScI conferences relevant to WFIRST Science:

- July 27-29, 2015:
  Mocking the Universe

- April 25-28, 2016:
  What Shapes Galaxies: rewriting the Hubble Sequence
- Nov 14-16, 2016:
  High Contrast Imaging with Space-Based Coronagraphs

- Feb 27 - Mar 2, 2017:
  Detecting the Unexpected: Discovery in Astronomically Big Data
- Spring-Summer 2017:
  Annual WFIRST Conference (title/details TBD)

Project Organization

- Going forward, STScI will focus on
  - Continuation of pre-formulation efforts
  - Support newly-selected Science Teams and Astronomical Community
  - preparations for its role in the WFIRST Science Operations
- Project organization (simplified):

NASA/GSFC

Project Office/Management
Mission Operations
Wide Field Imager
Spacecraft

NASA/JPL

Coronagraph
Telescope

Science Teams / FSWG

Science Planning
Science Algorithms/Analysis
High-level Data Products

Science Centers (GSFC, STScI, IPAC)

Scheduling
Calibration/User Support
Pipelines/Archive

Science Team Projects
(selected Dec 2015)

PI	PI Institution	Title	Topic
Olivier Dore	JPL	Cosmology with the WFIRST High Latitude Survey	Galaxy Redshift Survey, Weak Lensing Survey
Ryan Foley	Illinois	Optimizing the WFIRST Type Ia Supernova Survey	Supernovae Survey
Scott Gaudi	Ohio State	Preparing for the WFIRST Microlensing Survey	Microlensing Survey
Jeremy Kasdin	Princeton	WFIRST Coronagraph Instrument Adjutant Scientist	Coronagraph Instrument Adjutant Scientist
Jason Kalirai	STScI	Resolving the Milky Way with WFIRST	GI/GO
Bruce Macintosh	Stanford	Optimizing WFIRST Coronagraph Science	Coronagraphy
Saul Perlmutter	LBNL	Investigating the Nature of Dark Energy using Type Ia Supernovae	Supernovae Survey
James Rhoads	Arizona State	Cosmic Dawn with WFIRST	GI/GO
Brant Robertson	UC Santa Cruz	WFIRST Extragalactic Potential Observations	GI/GO
David Spergel	Princeton	WFIRST Wide Field Instrument Adjutant Scientist	Widefield Instrument Adjutant Scientist
Alexander Szalay	Johns Hopkins	Archival Research Capabilities of the WFIRST Data Set	GI/GO
Margaret Turnbull	SETI Institute	Harnessing the Power of the WFIRST Coronagraph	Coronagraphy
Benjamin Williams	Washington	WFIRST Infrared Nearby Galaxy Survey	GI/GO

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DARK ENERGY • EXOPLANETS • ASTROPHYSICS

Formulation Science Working Group

Name	**Affiliation**	**Role**
Neil Gehrels, **Chair**	NASA/GSFC	Project Scientist
David Spergel, **Deputy Chair**	Princeton University	WFI Adjutant Scientist
Jeremy Kasdin, **Deputy Chair**	Princeton University	CGI Adjutant Scientist
Dominic Benford, *ex officio*	NASA/HQ	Program Scientist
Dave Bennett	UMBC & GSFC	Microlensing
Ken Carpenter, *ex officio*	NASA/GSFC	Project science
Roc Cutri, *ex officio*	IPAC	Science center
Olivier Doré	NASA/JPL	Cosmology: GRS+WL
Ryan Foley	UIUC	Supernova Cosmology
Scott Gaudi	Ohio State U.	Microlensing
Chris Hirata	Ohio State U.	Cosmology: WL
Jason Kalirai	JHU & STScI	GI/GO – Galactic science
Jeff Kruk, *ex officio*	NASA/GSFC	Project science
Nikole Lewis	STScI	Coronagraph
Bruce MacIntosh	Stanford	Coronagraph
Roeland van der Marel, *ex officio*	STScI	Science center
S. Perlmutter	UC Berkeley	Supernova Cosmology
James Rhoads	Arizona State	GI/GO – Cosmic Dawn
Jason Rhodes, *ex officio*	NASA/JPL	Project science
Aki Roberge	NASA/GSFC	Coronagraph
Brant Robertson	UC Santa Cruz	GI/GO – Galaxy evolution
Alexander Szalay	Johns Hopkins	GI/GO – Archival science
Wes Traub, *ex officio*	NASA/JPL	Project science
Maggie Turnbull	GSI & SETI	Coronagraph
Yun Wang	Caltech/IPAC	Cosmology: GRS
David Weinberg	Ohio State Univ.	Cosmology: Clusters
Benjamin Williams	U. Washington, Seattle	GI/GO – Nearby Galaxies

Composition:

- NASA Project Scientist
- Adjutant Scientists
- Science Team PIs
- Select Deputies
- (Ex-officio) Project + Science Center Representatives

Science Center

- WIRST Science Center functions will be distributed between GSFC, STScI, IPAC
- Task division (for 2016-2018 formulation phase; simplified):
  - GSFC : Management/Strategic Guidance, Outreach, Call for Proposals/Grants, WFI Engineering
  - STScI : WFI, HLS, Archive, Scheduling
  - IPAC : CGI, MLS, GO/GI Selection, CGI Engineering(w/JPL)

  Leverage combined experience with NASA's Great Observatories
- Instrument tasks (WFI or CGI) include
  - commanding, GO planning/tools, calibration, Pipeline (to level 2b), SIT+user support, commissioning, community engagement
- STScI Phase A work will focus on development of requirements/concepts for the assigned areas

Science Center – Science Community Interaction

Ground System

STScI
IPAC
NASA/GSFC

Science Requirements
Observing Strategies
Analysis algorithms

Observations
Data products
Calibrations
Documentation
Analysis Tools

Ground-Breaking Science

Science Teams
Guest Observers
Archival Investigators

- WFIRST Mission has many partners with distributed expertise
- Let us know how we can help you!
- Please use our tools and reports
- Please provide feedback to help@stsci.edu

WFIRST
WIDE-FIELD INFRARED SURVEY TELESCOPE
DARK ENERGY • EXOPLANETS • ASTROPHYSICS

Conclusions

- STScI is actively engaged in preparation and planning for the mission
  - Many tools created to help science teams and community

- STScI is looking forward to collaborate with the FSWG, SITs, astronomical community, and other mission partners to
  - Build synergies
  - Leverage common tools
  - Help meet everyone's Phase A deliverables
  - Create a successful WFIRST mission!