WFIRST & AFTA

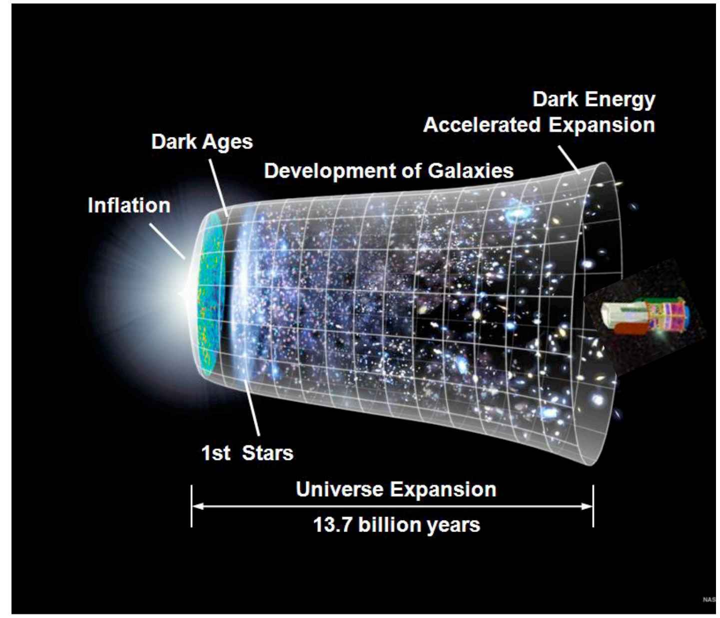
Neil Gehrels (GSFC) SDT Co-Chair
David Spergel (Princeton) SDT Co-Chair

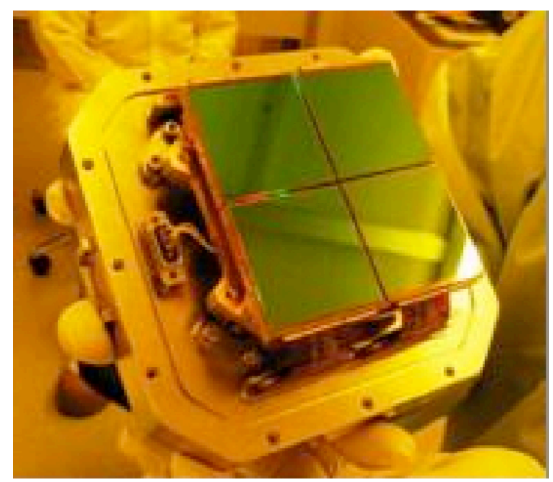
AAS MEETING PHYSPAG SUBCOMMITTEE

JANUARY 6, 2013

WFIRST Summary

- WFIRST is the highest ranked large space mission in 2010 US Decadal Survey
  - dark energy
  - exoplanet microlensing and coronagraphy
  - NIR sky for the community (GI program)
- Measurements:
  - NIR sky surveys for BAO and weak lensing
  - NIR monitoring for Type Ia supernovae
  - Option coronagraph for exoplanet imaging
- Enabled by US-developed large format HgCdTe detectors





JWST HgCdTe Detector

WFIRST Activities

WFIRST

- 2010: WFIRST ranked 1st in large mission category by Astro2010
- 2011: Science Definition Team #1 formed to study WFIRST
- 2011: Nobel prize for acceleration of universe
- 2011: Free-floating planets detected by ground microlensing
- 2012: WFIRST science conference at Caltech (February)
- 2012: SDT #1 final report (June)

AFTA-WFIRST

- 2012 NASA announces receipt of two 2.4m telescopes (June)
- 2012 Ad-hoc science group considers applicability for WFIRST science
  - white paper: arXiv 1210.7809
- 2012 WFIRST-AFTA science conference at Princeton (September)
- 2012 SDT #2 formed to study using 2.4m telescope for WFIRST science
  - working with Project team at Goddard and JPL

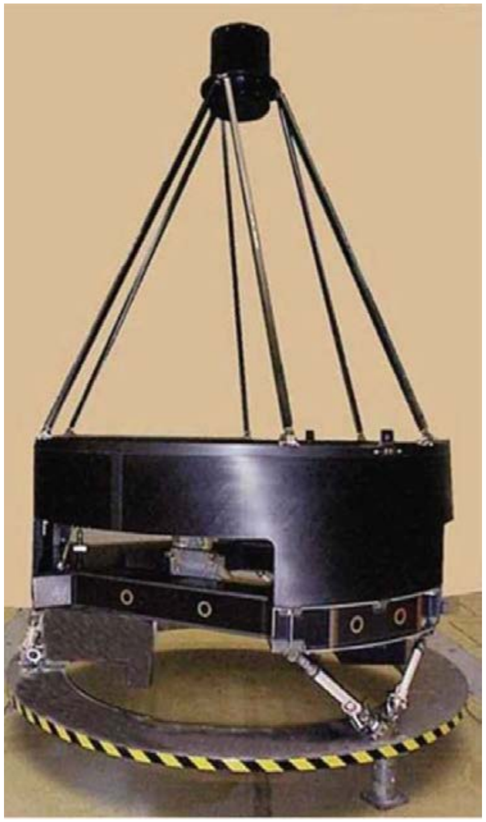
Program to package & characterize HgCdTe IR detectors (govt, industry, academia)

Science Definition Team #2

Neil Gehrels, GSFC Co-Chair
David Spergel, Princeton Co-Chair

James Breckinridge, Caltech
Megan Donahue, Michigan State Univ.
Alan Dressler, Carnegie Observatory
Chris Hirata, Caltech
Scott Gaudi, Ohio State Univ.
Thomas Greene, Ames
Olivier Guyon, Univ. Arizona
Jason Kalirai, STScI
Jeremy Kasdin, Princeton
Warren Moos, Johns Hopkins
Saul Perlmutter, UC Berkeley / LBNL
Marc Postman, STScI
Bernard Rauscher, GSFC
Jason Rhodes, JPL
Yun Wang, Univ. Oklahoma
David Weinberg, Ohio State U.

Wes Traub, JPL Ex-Officio
Rita Sambruna, NASA HQ Ex-Officio



AFTA
Astrophysics Focused
Telescope Assets

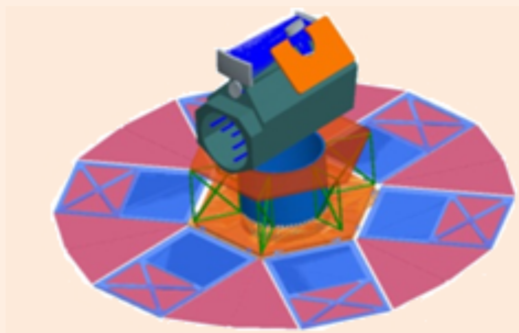
SDT Charter

- Determine science requirements and key mission parameters
- Work with Project office to develop a Design Reference Mission using one of the 2.4m telescope assets
- Use telescope "as is"
- Maintain the technical viability for a 2022 launch
- Incorporate modularity in design and attach points to facilitate on-orbit servicing and I&V testing. Consider GEO orbit.
- Keep overall mission cost as low as possible
- Study including a coronagraph instrument as an option
- Study utilizing optical communication as an option

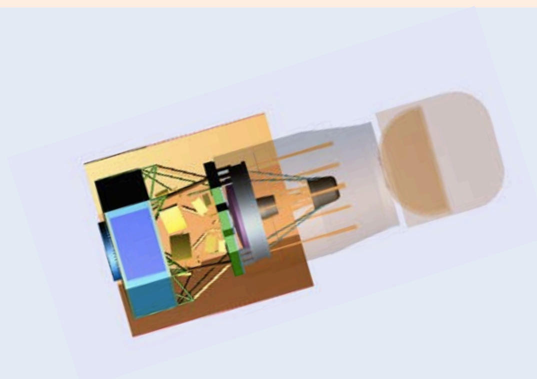
Design Concepts

- **DRM1**
  - **1.3 meter off-axis telescope**
  - **Single channel payload**
  - **5 year mission**
  - **Atlas V Launch Vehicle**

- **DRM2**
  - **1.1 meter off-axis telescope**
  - **Single channel payload**
  - **3 year mission**
  - **Falcon9 Launch Vehicle**

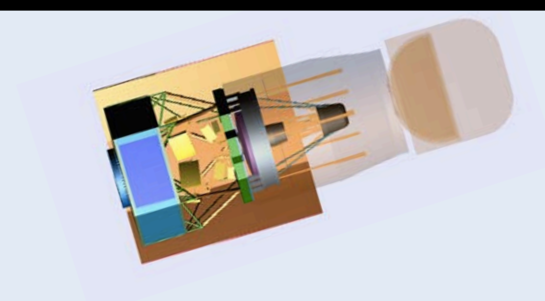


- **AFTA-WFIRST**
  - **2.4 meter on-axis telescope**
  - **1-channel payload + coronagraph**
  - **5 year mission**
  - **Falcone9 or Atlas V Launch Vehicle**



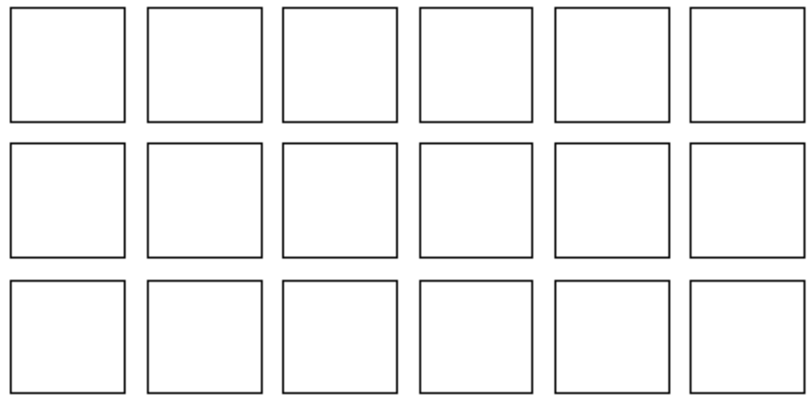
Design Concepts

- 2.4 meter on-axis telescope
- 1-channel payload + coronagraph
- 5 year mission
- Falcon 9 or Atlas V Launch Vehicle



Field of View

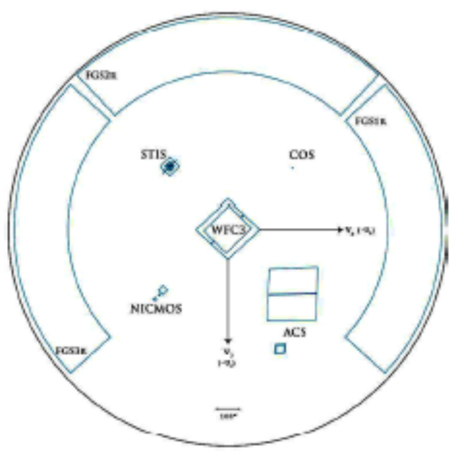
6x3 H4RG @ 0.11"/p, 0.28 sq.deg



288 Mpix

0.425 wide°

0.874°

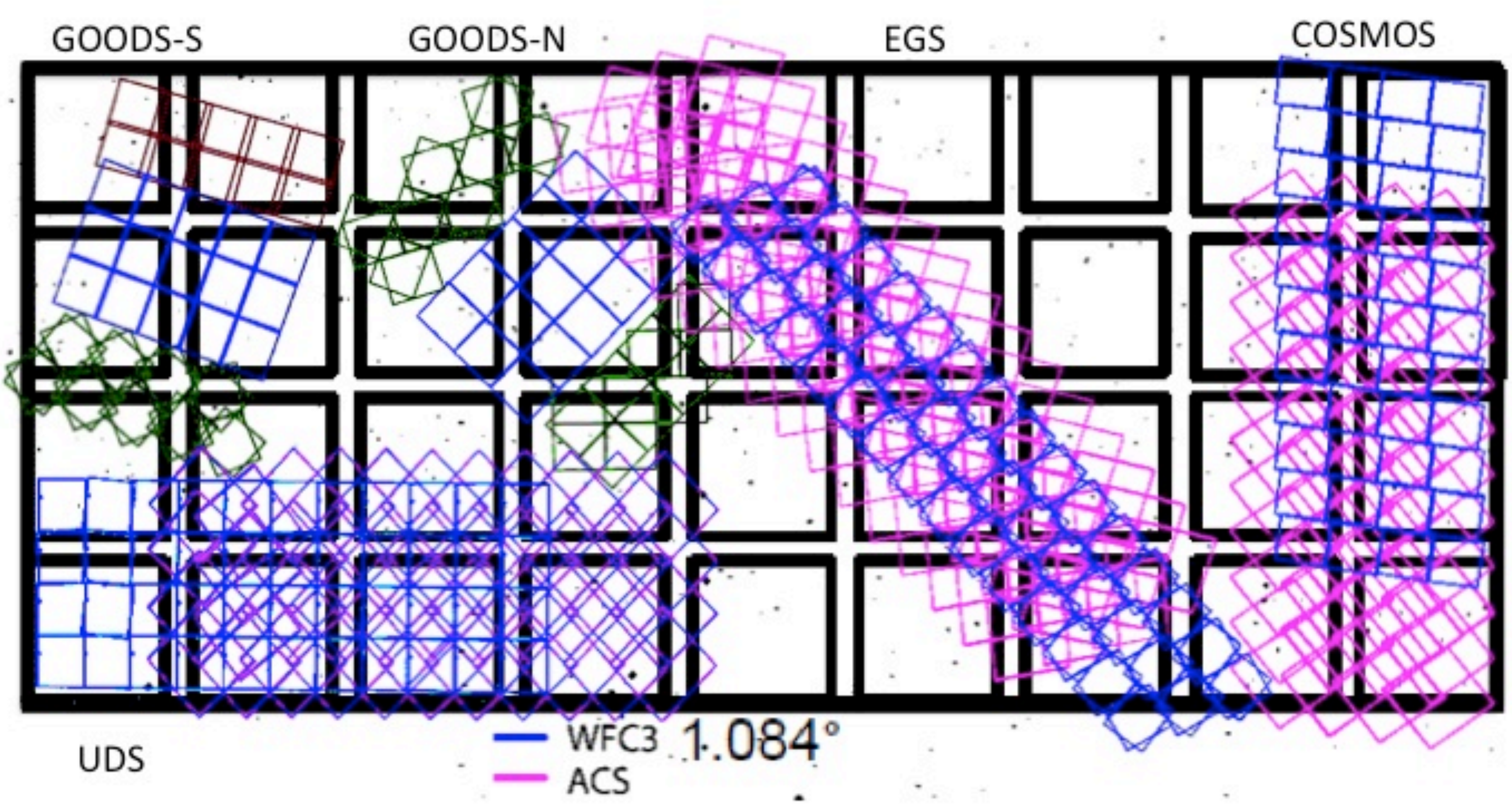


HST [all instruments]

JWST [all instruments]

Moon (average size seen from Earth)

CANDELS fields on DRM1 focal plane



from J. Kruk

Advantages of 2.4m Telescope

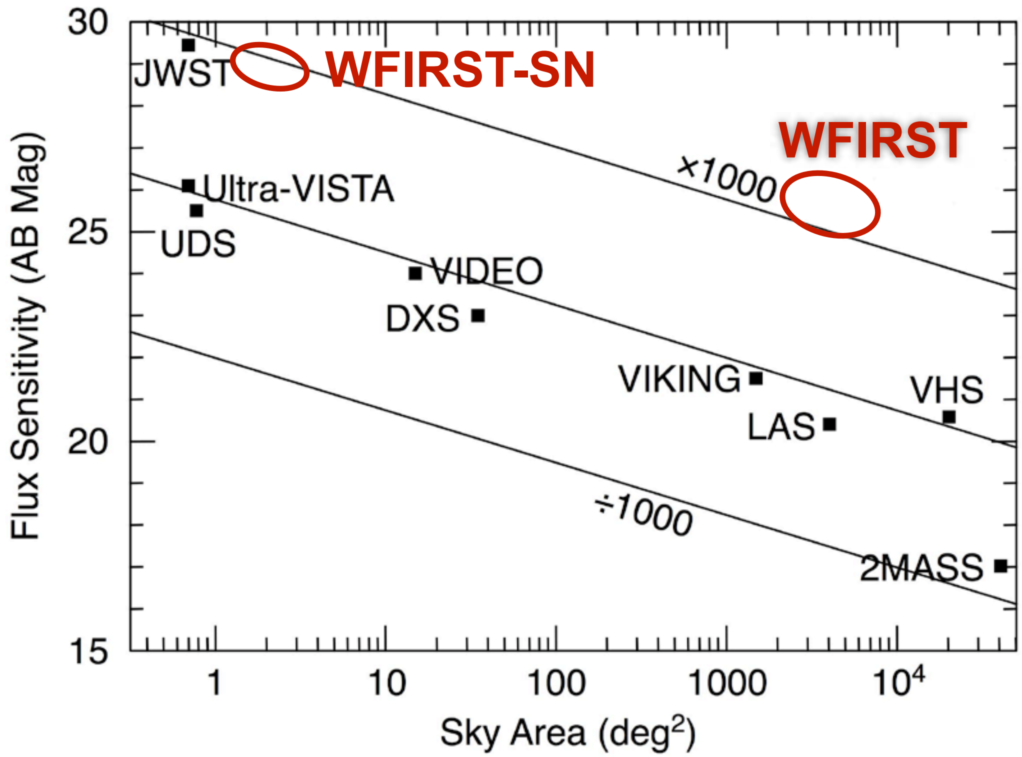
- All configurations studied have excellent science performance relative to Astro2010 goals:
  - DRM 1: Astro2010 prescription
  - DRM2: Low cost, but capable due to larger pixel count
- Gift telescope at no cost to NASA.
- Existing hardware.
- Telescope PSF is factor of 1.8 – 2.2 better than DRM 1 & 2
  - Angular resolution scales at ~ λ / D
  - Enables optional coronagraph
- Larger mirror gives factor ~2 better sensitivity (0.8 mag deeper)

Near IR Capabilities

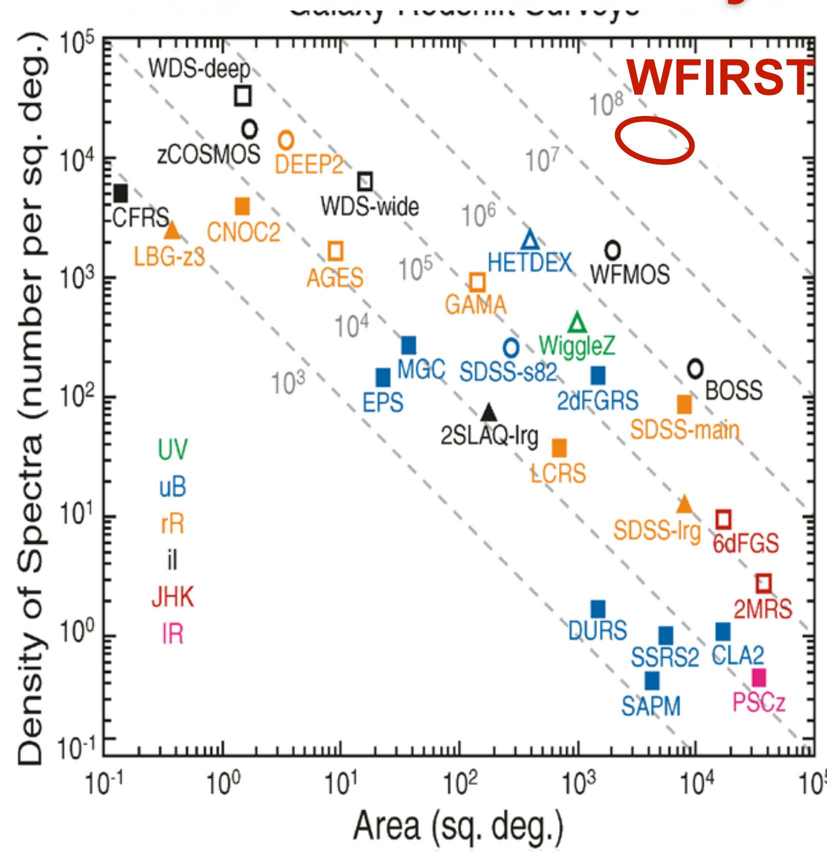
instrument	telescope	pixel scale	field of view	wavelength
WISE	0.4m	2.75 arcsec	47 arcmin	3 – 28 μm
ISO	0.6m	12 arcsec	3 arcmin	2.4 – 240 μm
Akari	0.7m	1.5 arcsec	10 arcmin	1.8 – 180 μm
Spitzer	0.85m	1.2 arcsec	5.2 arcmin	3 – 8 μm
Hubble/NICMOS	2.4m	0.04 – 0.20 arcsec	0.2 – 0.9 arcmin	0.8 – 2.5μm
Hubble/WFC3 IR	2.4m	0.13 arcsec	2 arcmin	0.9 – 1.7 μm
AFTA-WFIRST	**2.4m**	**0.11 arcsec**	**25 x 52 arcmin**	**1.0 – 2.0 μm**

WFIRST NIR Surveys

NIR Imaging Surveys



NIR Redshift Surveys



WFIRST provides a factor of 100 improvement in IR surveys

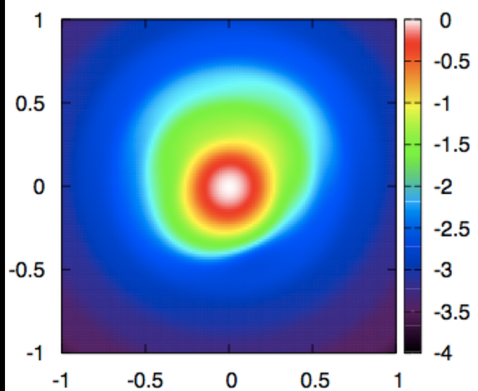
Basic Parameters

	DRM2	DRM1	DRM0
Collecting area (m^2)	0.91	1.27	3.37
Field of view (deg^2)	0.585	0.375	0.281
Etendue (m^2 deg^2)	0.53	0.48	0.95
N_{pix}	234 M	150 M	301 M
Detectors	14× H4RG	36× H2RG	18× H4RG
Primary mission duration (yr)	3	5	5?
Pixel scale P (arcsec)	0.18	0.18	0.11
Critical wavelength $\lambda_c = DP$ (μm)	0.94	1.11	1.24
PSF half light radius in J/H band (arcsec)	0.20/0.22	0.17/0.19	0.13/0.15
Telescope temperature (K)	205	205	250—280

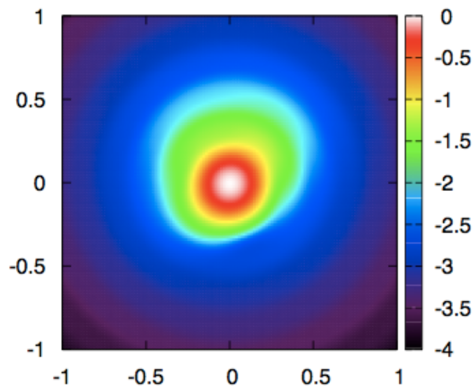
With thanks to C. Hirata..

Point spread functions

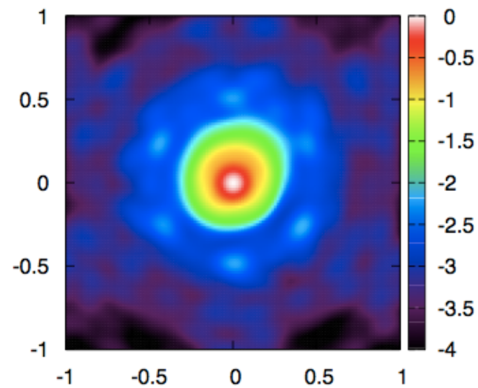
- Wavelength 1.2 μm, monochromatic
- Includes diffraction, pixel response, and jitter
- Aberrations: 71 nm rms wfe, equally distributed in focus, astigmatism, coma
- Postage stamps are 2×2 arcsec
- Color scale is $\log_{10}$(intensity)



DRM2



DRM1



DRM0

PSF effective area, Ω_{eff}

Units are square arcsec

	DRM2	DRM1	DRM0
Z	0.298	0.217	0.119
Y	0.325	0.236	0.138
J	0.378	0.274	0.165
H	0.472	0.340	0.204
K [K_s]	0.629	0.452	 [0.246]

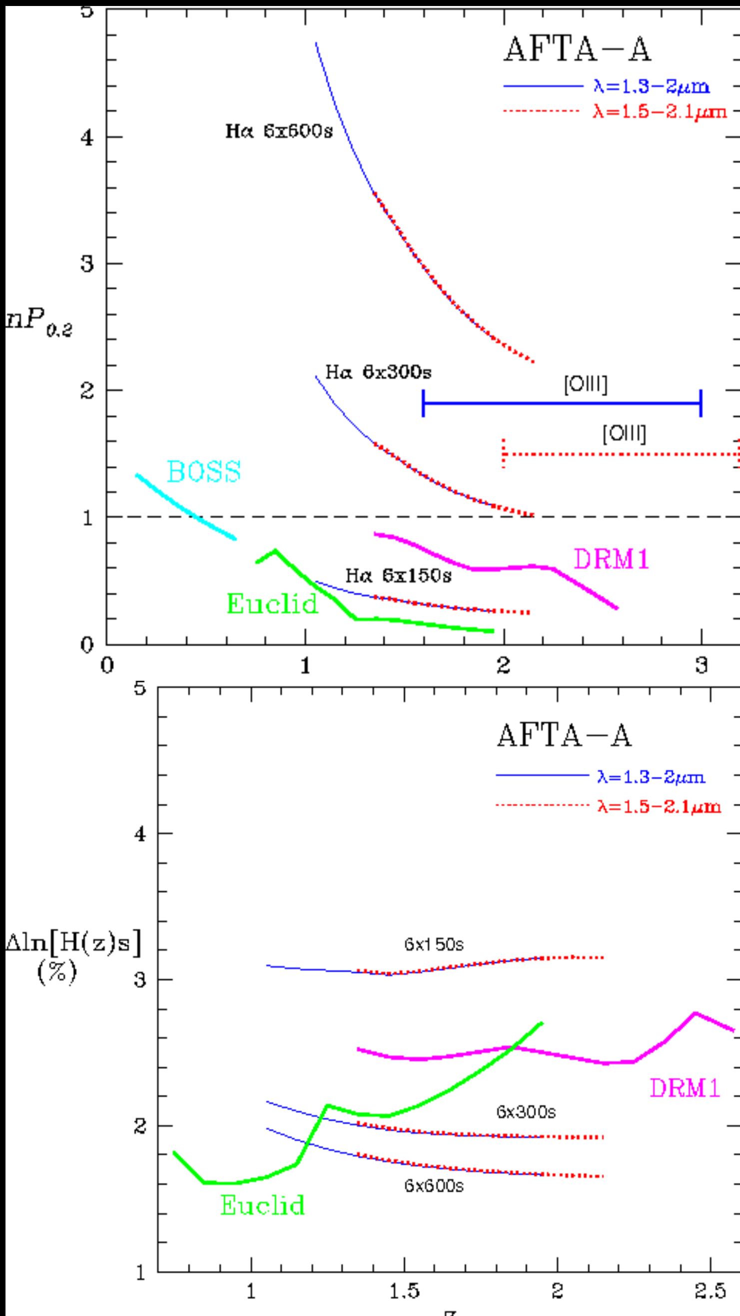
DRM0 is 2.3—2.5x better than DRM2, and 1.7—1.8x better than DRM1.

Take the square root of these numbers to get a PSF in "linear" units instead of area units (arcsec instead of $arcsec^2$).

Results at T_{tel} = 250 K (imaging)

	Case A	Case B	Case C
Y	5 x 94 s **25.93**	5 x 131 s **26.39**	5 x 247 s **27.10**
J	6 x 84 s **25.92**	6 x 115 s **26.37**	6 x 205 s **27.02**
H	5 x 94 s **25.95**	5 x 131 s **26.40**	5 x 247 s **27.07**
K_s	5 x 147 s **25.82**	5 x 246 s **26.33**	5 x 247 s **26.33**
Time (days per 1000 deg^2)	**128** [87 without K_s]	**178** [113 without K_s]	**260** [195 without K_s]

- Table shows exposure times and depth (5σ pt src, AB mag)
- DRM2 uses **126** days per 1000 deg^2 (would be 94 days without K filter)
- Assumed a "K_s" filter at 1.83—2.15 µm in place of DRM1/2 K filter.



BAO (Galaxy Clustering) with WFIRST-AFTA

Yun Wang, Chris Hirata, & David Weinberg

SDT #1, Nov 2012

- **AFTA-A: 0.11″pixel, 6x3 chips, FoV=0.281 $(\mathrm{deg})^2$; telescope temperature: 250K**
- **[OIII] emitters could extend the WFIRST-AFTA survey to z~3.**
- **For 6x300s over 4000 sq deg (~300 days), the BAO precision is significantly better than Euclid and DRM1 at all redshifts surveyed.**
- **For 6x150s over 4000 sq deg, the precision is substantially worse than Euclid & DRM1.**
- **With ~300 days of observing time, the AFTA galaxy redshift survey would be a substantial advance in dark energy discovery potential.**

Unique science enabled by larger telescope

- ★ High order arc statistics (shaplets, etc.)
- ★ Significantly better supernova science (particularly with IFU)
- ★ Cluster counts, higher order lensing statistics
- ★ Increased complementarity to Euclid: significantly deeper and higher resolution (but will cover less area)
- ★ GENERAL ASTROPHYSICS

How does AFTA/WFIRST compare with previous concepts

- Faster? Probably
- Cheaper? Probably not
- Better? Definitely!!!
  - improved DE, microlensing science
  - coronagraphic science
  - significantly stronger general astrophysics
- More science to dollar; More complementary to Euclid

Dark Matter and Dwarfs

- For a S/N =100 object should achieve 80 micro-as/year proper motion measurements for field stars

- Accurate study of dark matter in tidal tails measurements of dwarfs and GC

- Tests of warm (and self-interacting) dark matter [and standard CDM].

Study Schedule

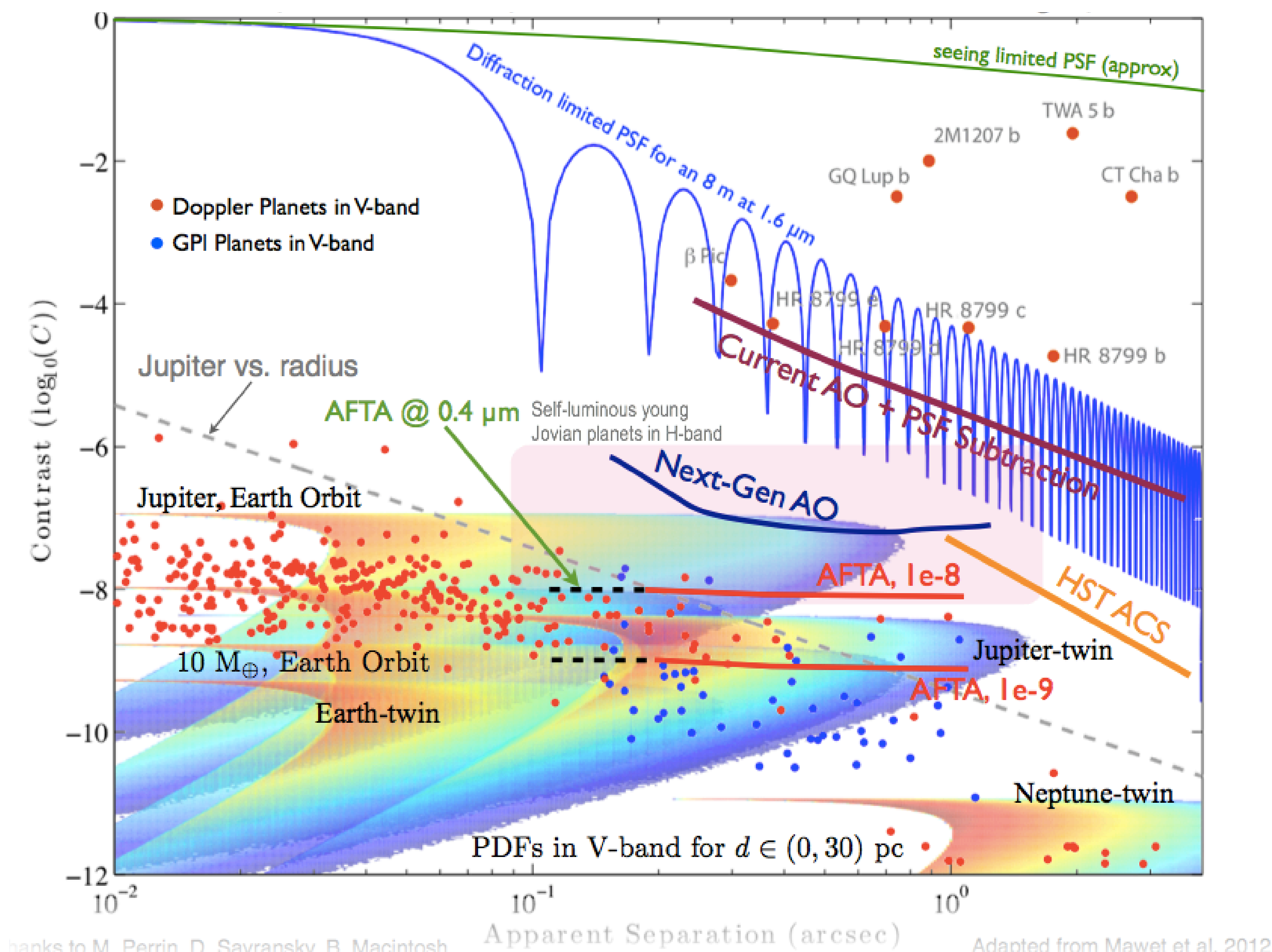
- SDT Meetings
  - Nov 19-20, 2012   GSFC
  - Jan 10-12, 2013   JPL / Caltech
  - Mar 14-15, 2013   GSFC
  - plus weekly telecons

- Report due April 30, 2013

- Independent cost estimate by end April

- AAS evening public session in Long Beach - Jan 8, 2012

Coronagraph Science



from
J. Kasdin