WFIRST

SCIENCE DEFINITION TEAM

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STUDY OFFICE: Richard Barry, Ed Cheng, Dave Content, Kevin Grady, Cliff Jackson, Jeff Kruk, Mark Melton, Norm Rioux

WFIRST: WHAT IT IS *NOT*

a dark energy mission
an exoplanet microlensing mission
an infrared sky survey
the creation of Astro2010

WFIRST: WHAT IT *IS*

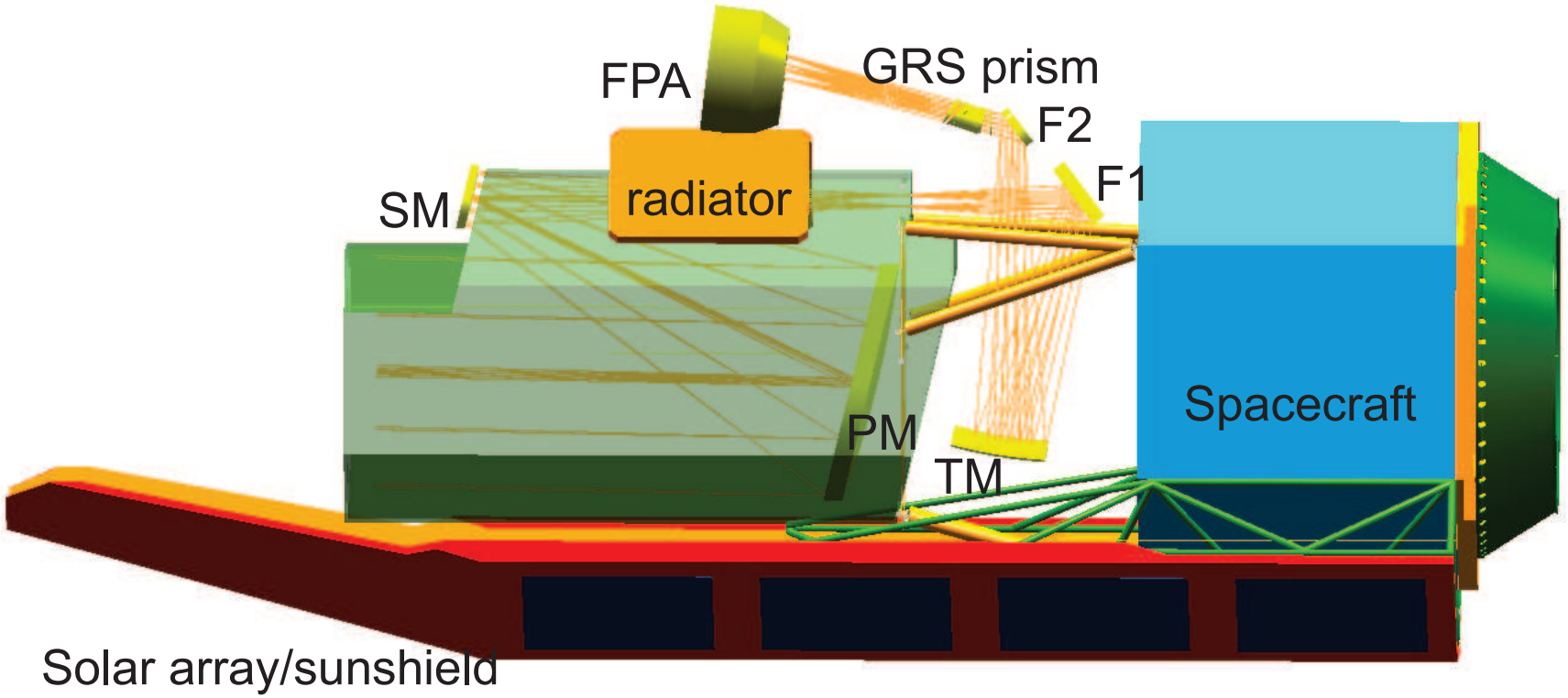
A Wide-Field Infrared Survey Telescope

imager to 2.4 μm with 2×10^8 HgCdTe pixels
a 205K unobstructed *three* mirror anastigmat
slitless spectrometer: $R = 75$ & $R = \frac{200''}{\theta_{FWHM}}$

WFIRST's Multiple Incarnations

version	CATE DATE	diameter	obstructed	red limit	number cameras	detectors
JDEMΩ	2010	1.5-m	yes	2.1μ	3	36 H2RG-18
IDRM	2011	1.3-m	no	2.1μ	3	36 H2RG-18
DRM1	2012	1.3-m	no	2.4μ	1	36 H2RG-18
DRM2	2012	1.1-m	no	2.4μ	1	14 H4RG-10
NRO	2013	2.4-m	yes	??	1	(20 H4RG-10)

WFIRST DRM1
Observatory Layout & Ray Trace

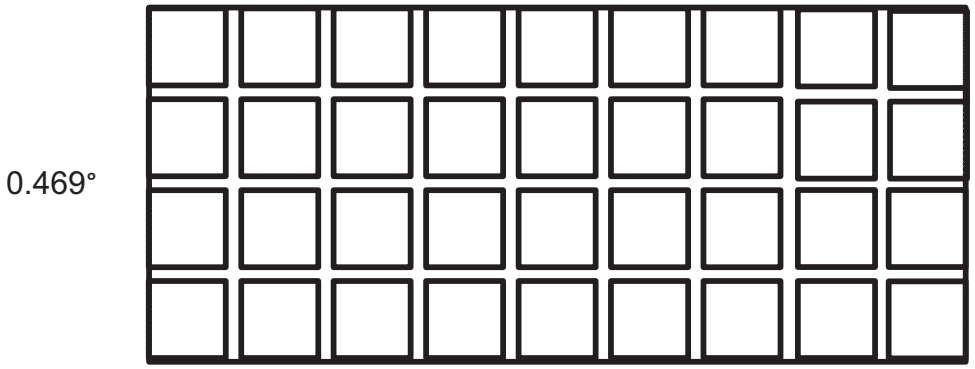


Channel field layout for WFIRST DRM1

1.3m uTMA, 9x4 single channel @0.18"/H2RG pixel

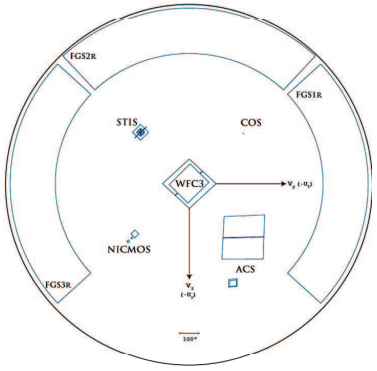
The Field of view of the single imaging & spectroscopy channel is shown to scale with the Moon, HST, and JWST. Each square is a 4Mpix vis-NIR sensor chip assembly (SCA)

Single channel FPA: 9x4 @ 0.18"/p;

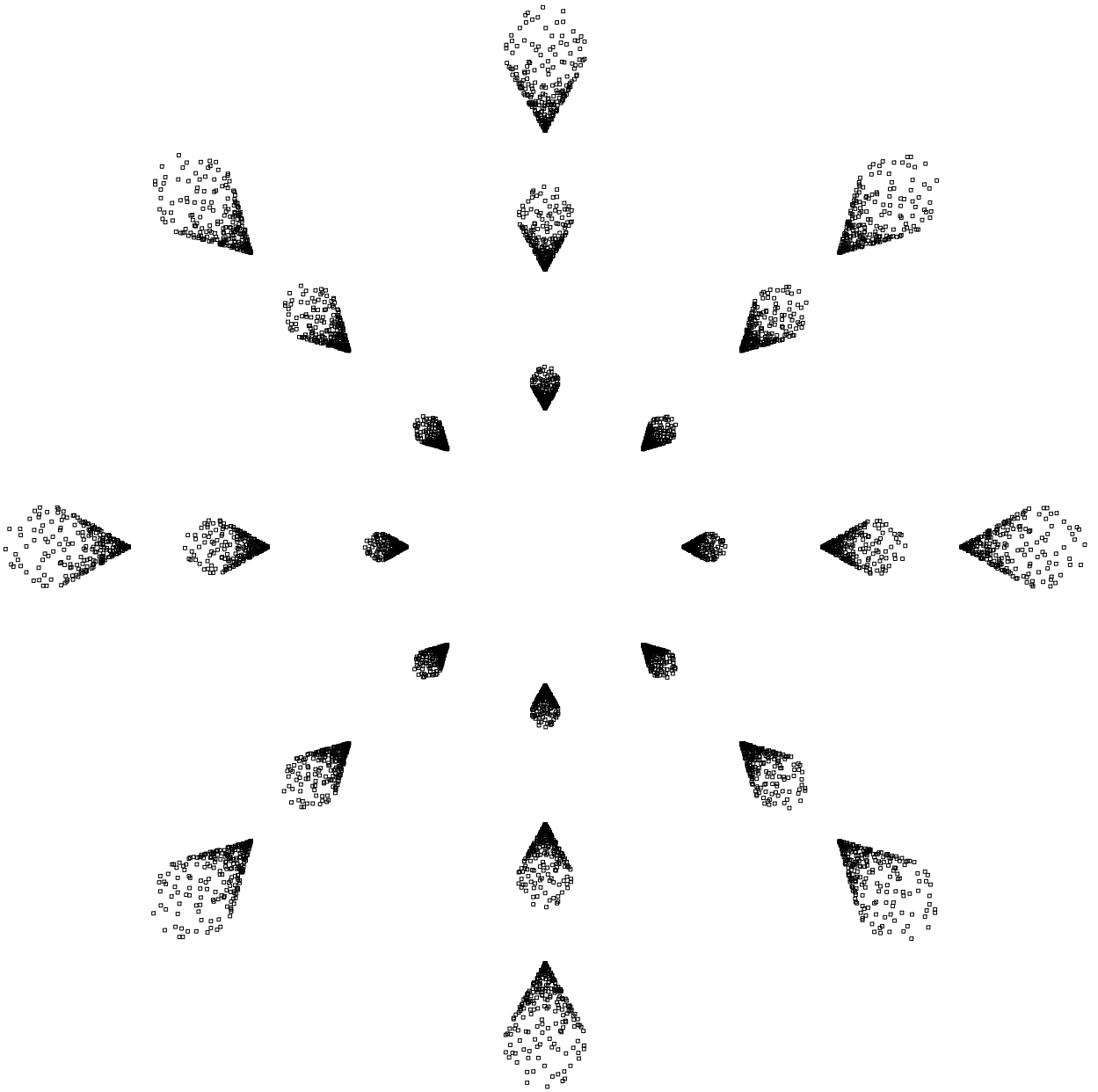


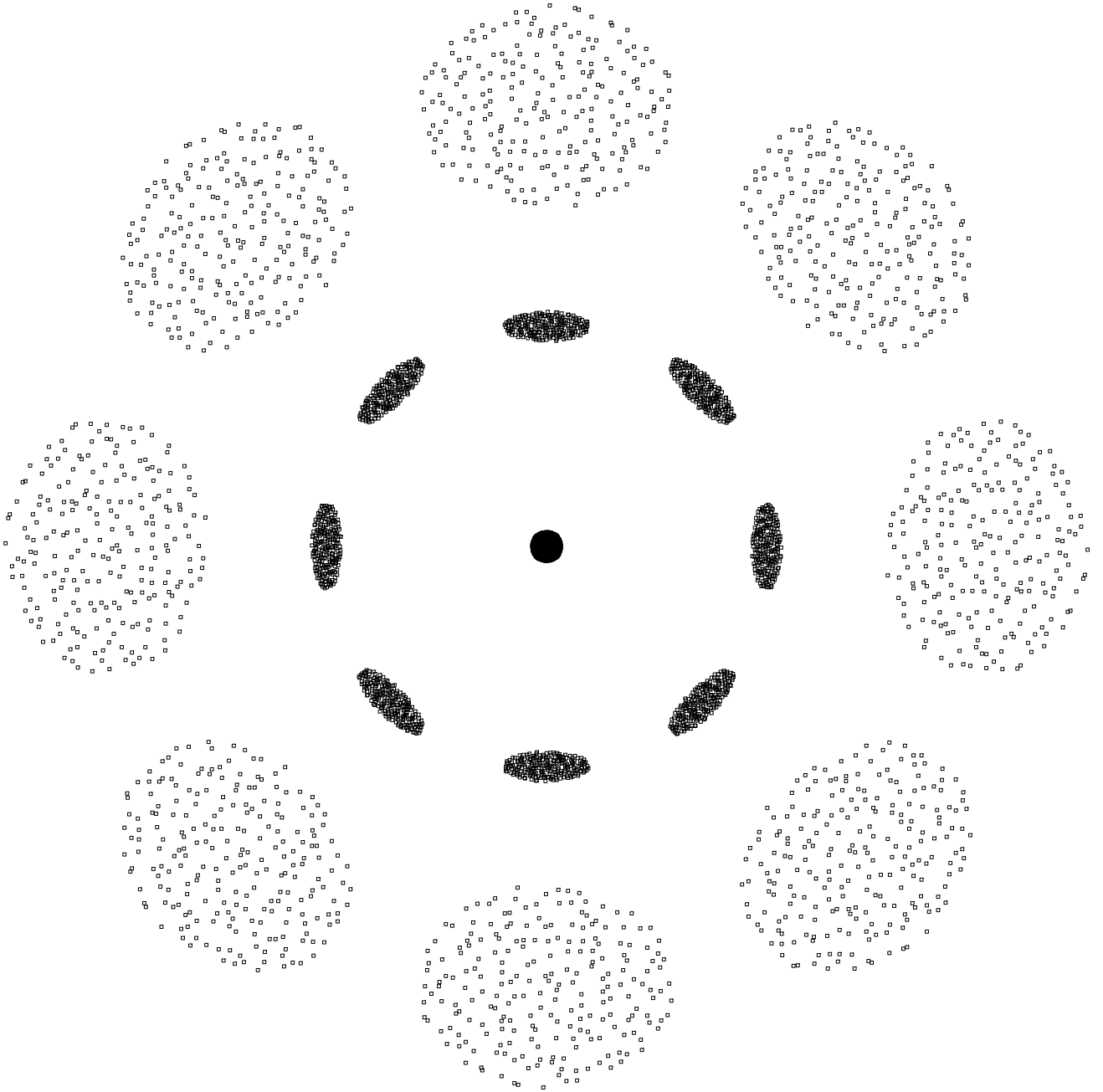
Moon (average size seen from Earth)

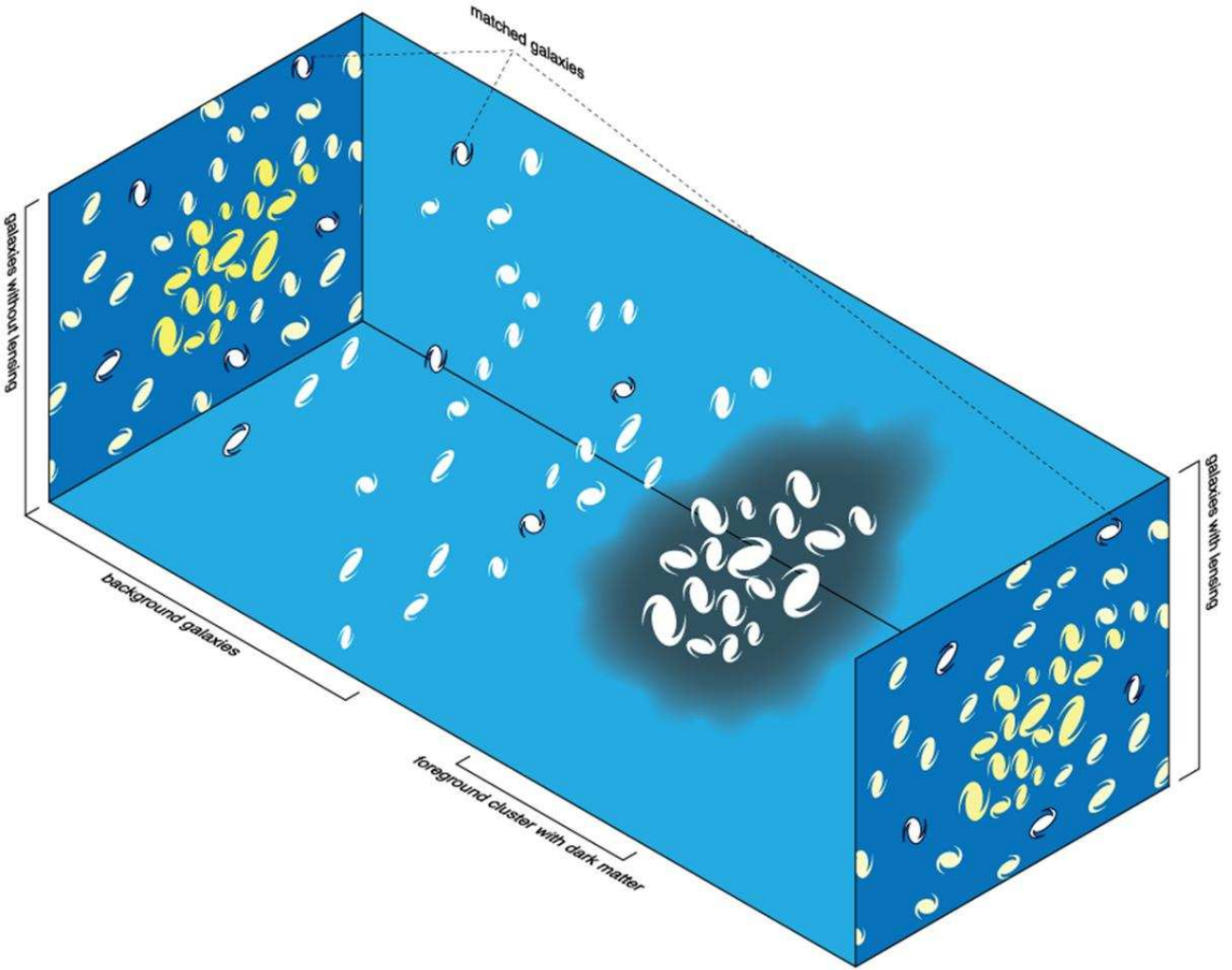
JWST [all instruments]



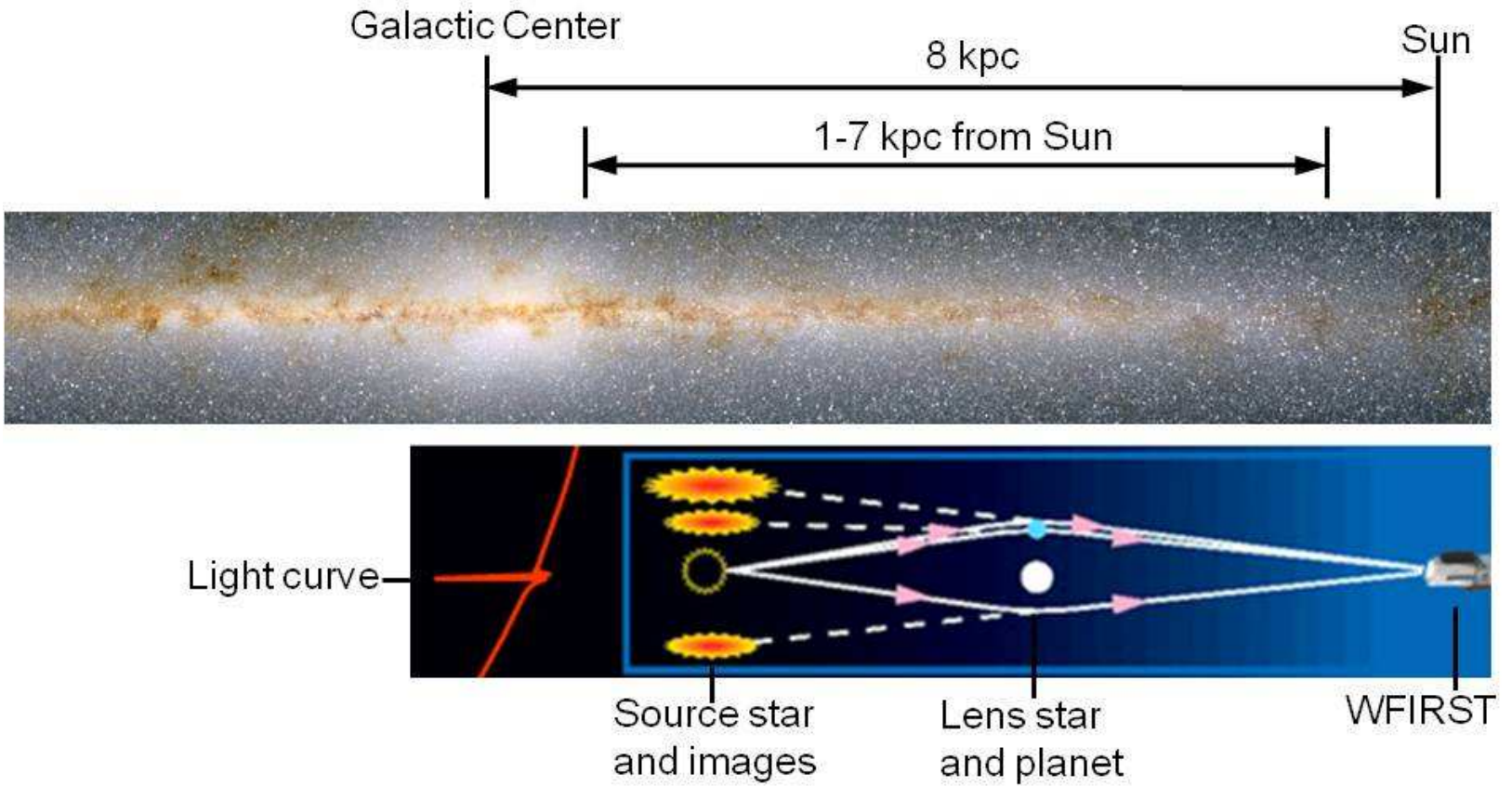
HST [all instruments]

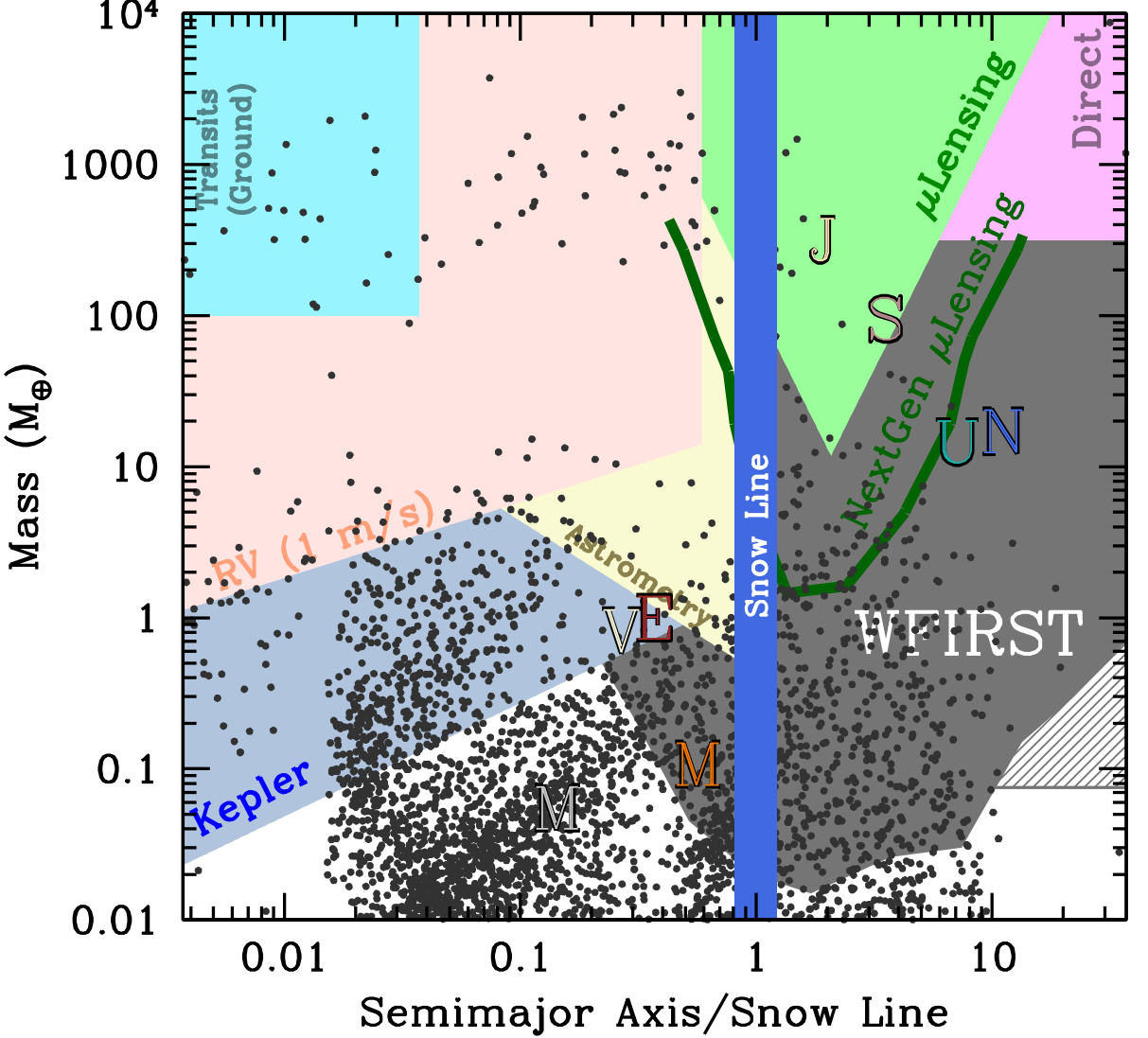





matched galaxies
galaxies without lensing
background galaxies
foreground cluster with dark matter
galaxies with lensing

Planetary Microlensing




Transits (Ground)
RV (1 m/s)
Astrometry
Kepler
Snow Line
μLensing
Direct
NextGen μLensing
WFIRST
J
S
UN
VE
M
M
Mass (M⊕)
Semimajor Axis/Snow Line
10⁴
1000
100
10
1
0.1
0.01
0.01
0.1
1
10

18 December 1998

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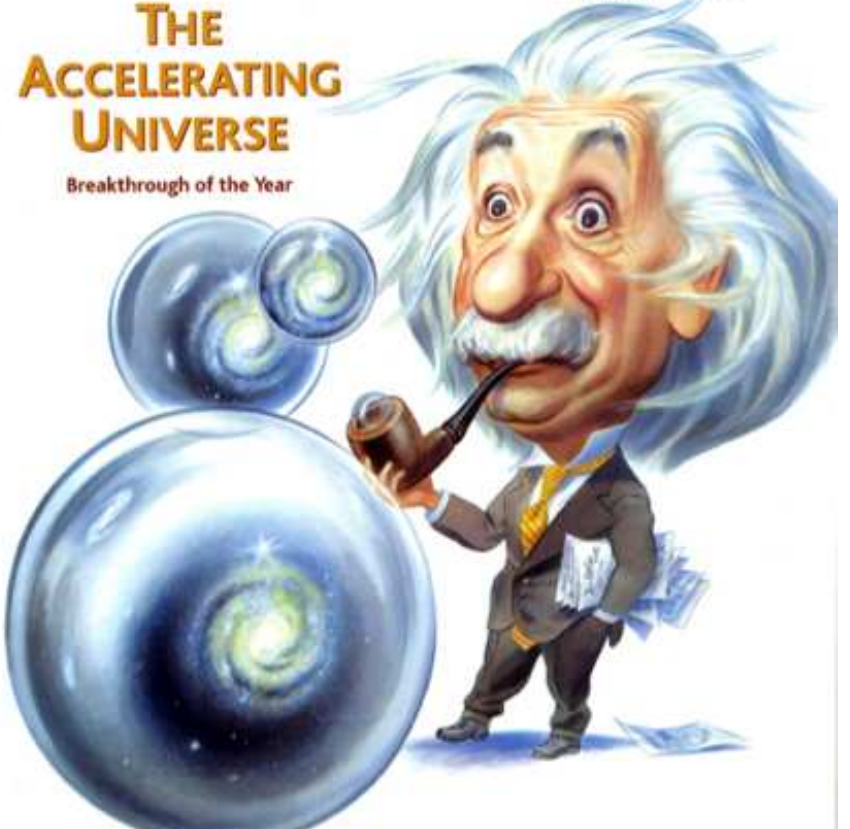
THE ACCELERATING UNIVERSE

Breakthrough of the Year

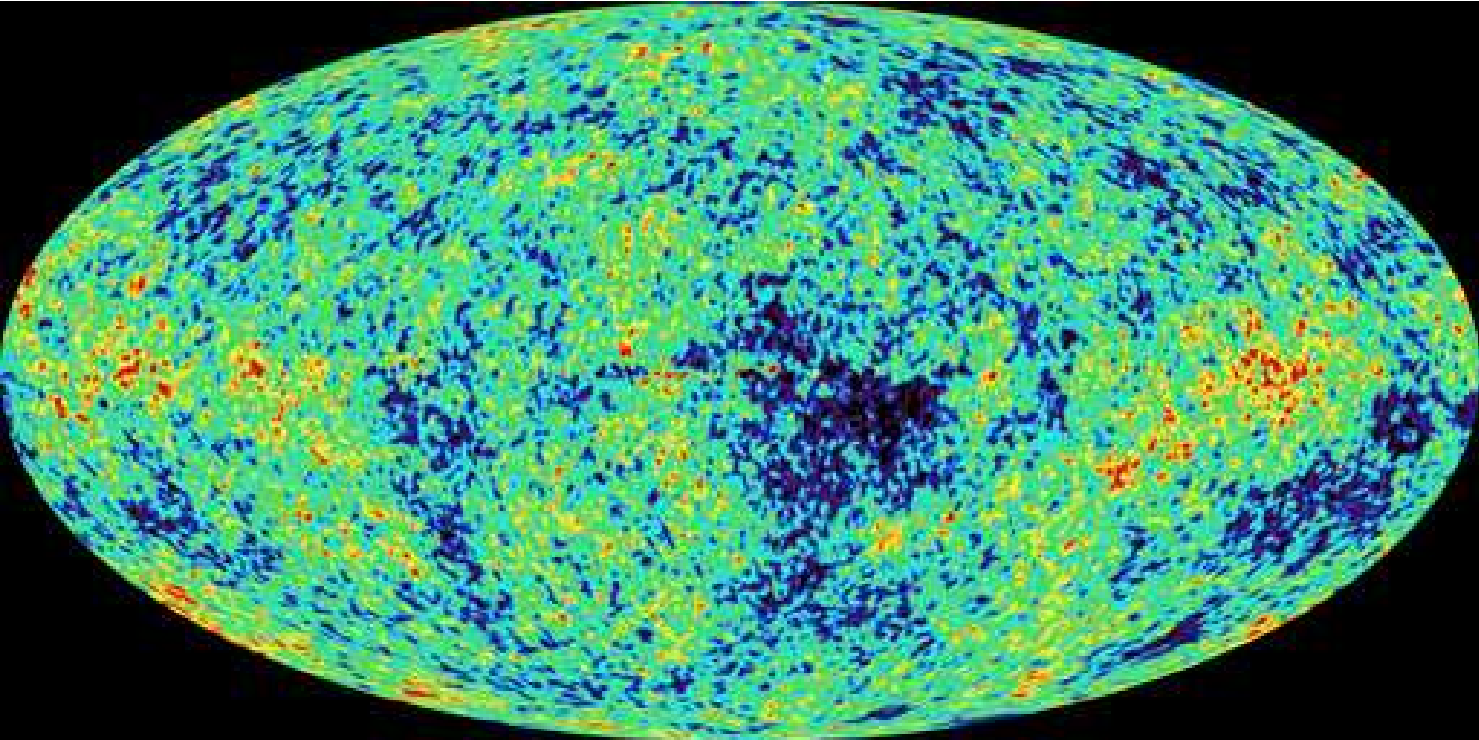


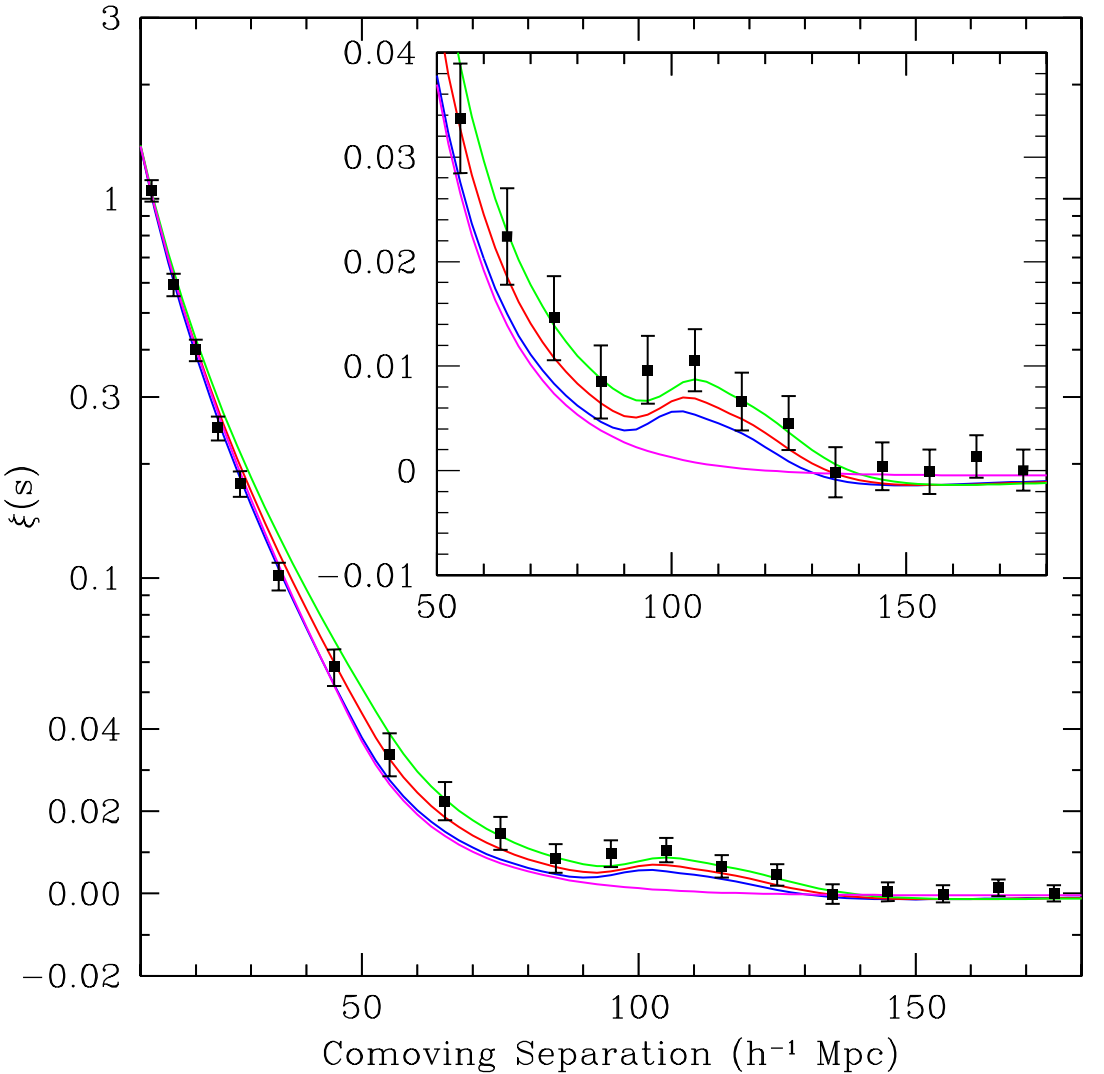
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

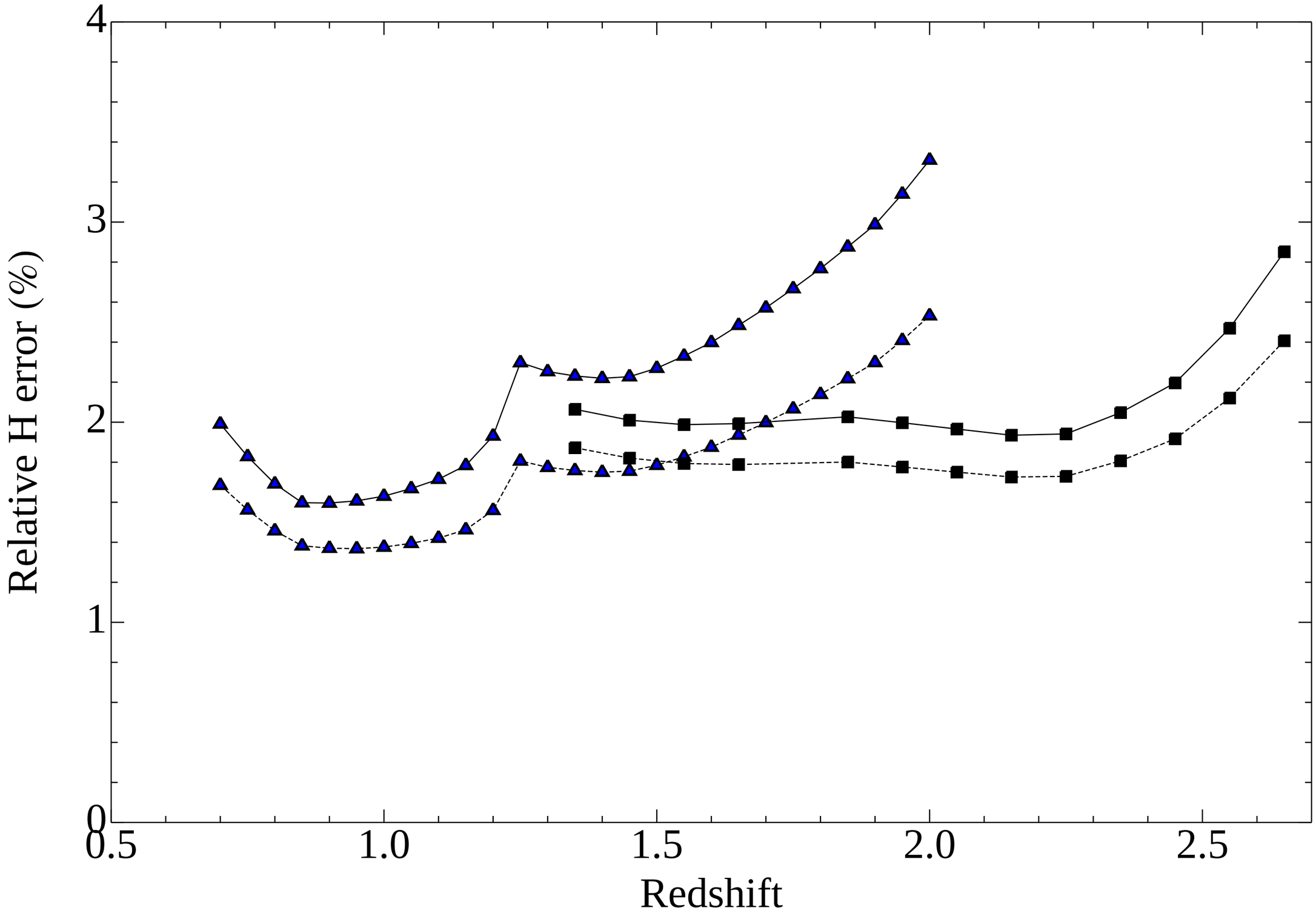
IF general relativity is correct then:

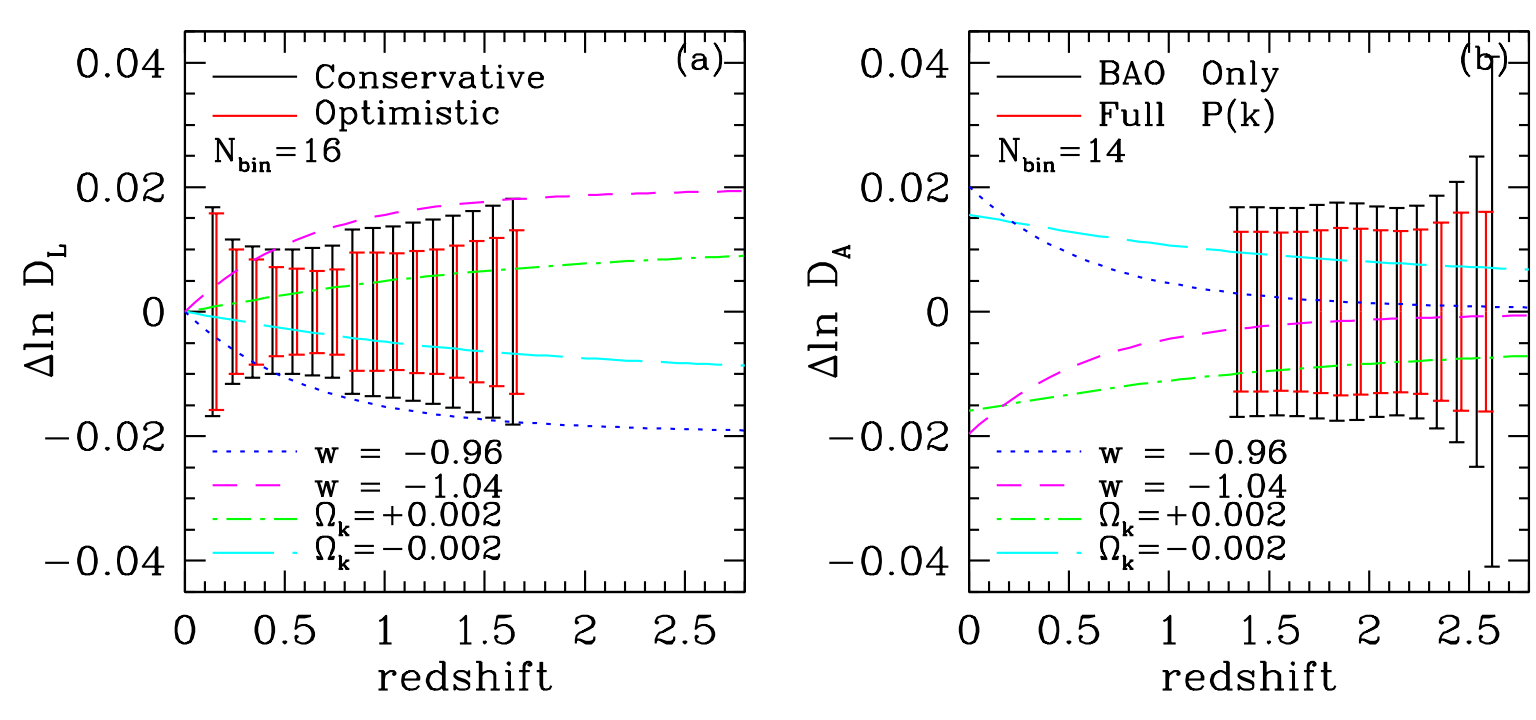
$$H(z)^2 = H_0^2[\underbrace{\Omega_m(1+z)^3}_{\text{matter}} + \underbrace{\Omega_r(1+z)^4}_{\text{radiation}} + \underbrace{\Omega_w(1+z)^{3(1+w)}}_{\text{dark energy}} + \underbrace{\Omega_k(1+z)^2}_{\text{curvature}}],$$

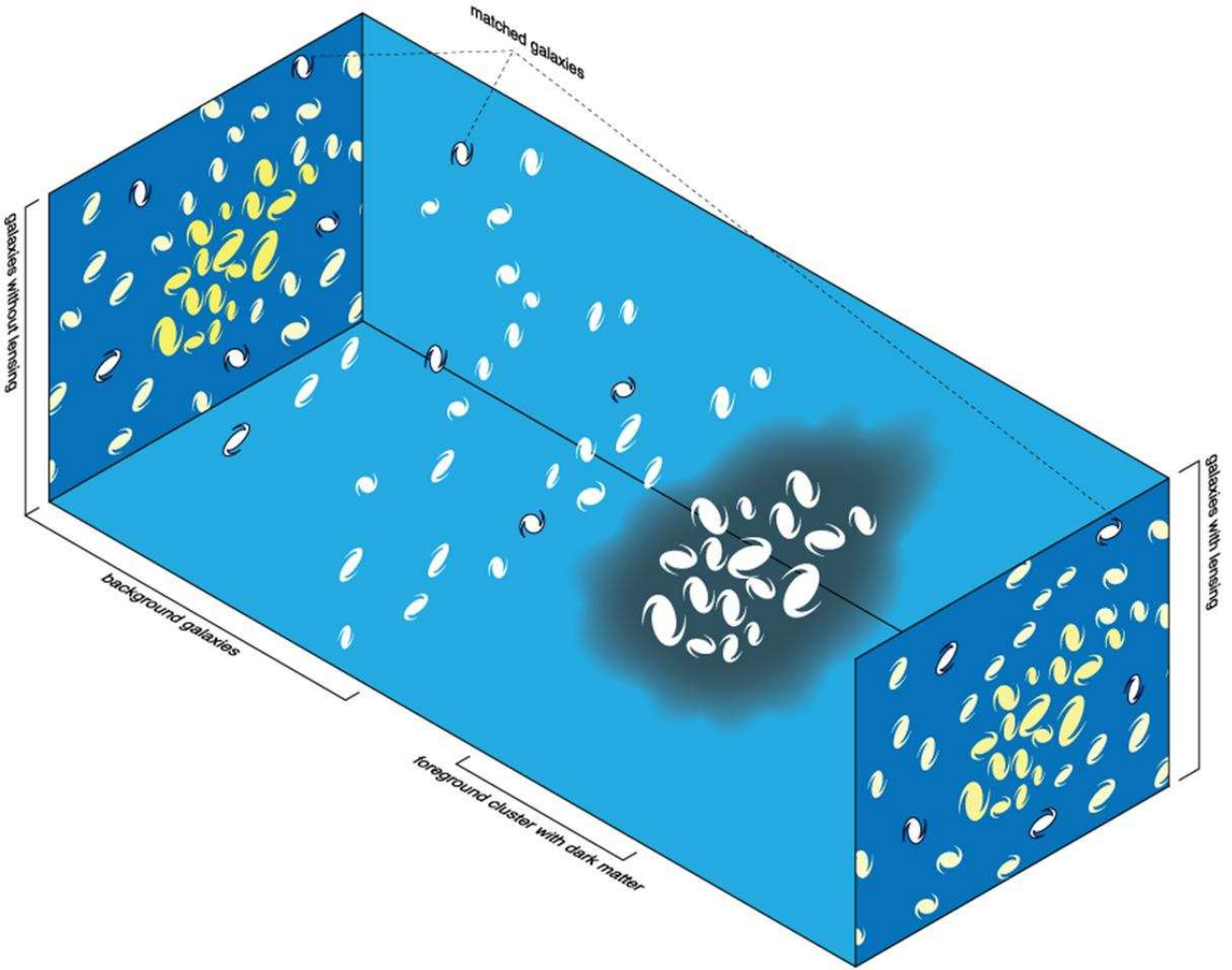
where $w = -1 \Leftrightarrow$ cosmological constant Λ.




3
1
0.3
0.1
0.04
0.02
0.00
−0.02
ξ(s)
50
100
150
Comoving Separation (h⁻¹ Mpc)
0.04
0.03
0.02
0.01
0
−0.01
50
100
150


Relative H error (%)
0
1
2
3
4
0.5
1.0
1.5
2.0
2.5
Redshift


(a)
Conservative
Optimistic
N_bin=16
w = −0.96
w = −1.04
Ω_k=+0.002
Ω_k=−0.002
Δln D_L
redshift
0.04
0.02
0
−0.02
−0.04
0
0.5
1
1.5
2
2.5
(b)
BAO Only
Full P(k)
N_bin=14
Δln D_A
redshift


matched galaxies
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$$\begin{pmatrix} \textbf{uncertainty in local} \\ \textbf{mean image ellipticity} \end{pmatrix} < \mathbf{0.0005}$$

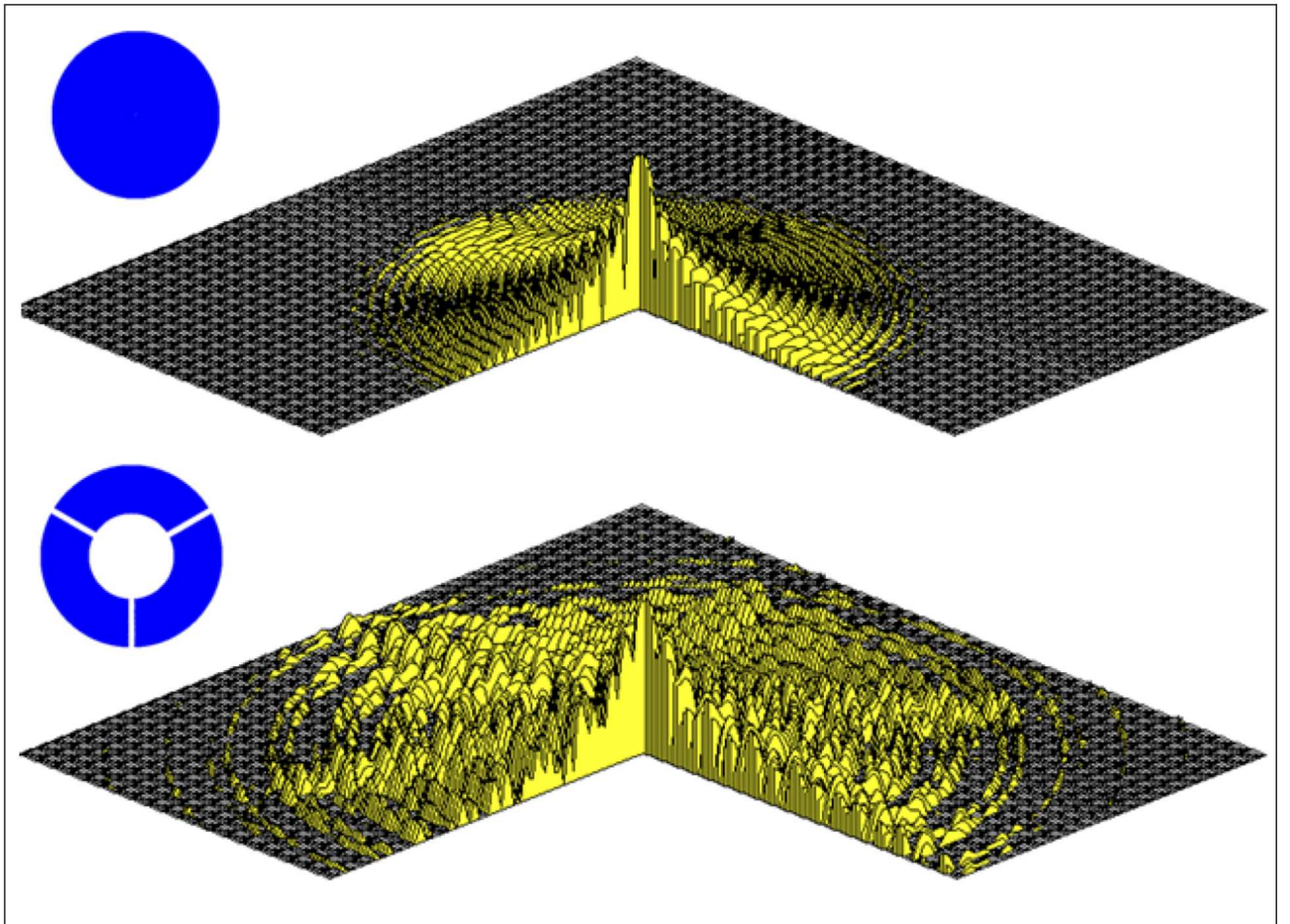


Figure 7: Monochromatic diffraction for unaberrated pupils. Top: an unobscured pupil. Bottom: pupil obscured by a centered 50% linear disk and three spider legs. Pupils are shown at the upper left. Logarithmic vertical scale spans four decades. Fresnel-Kirchoff diffraction assumed.

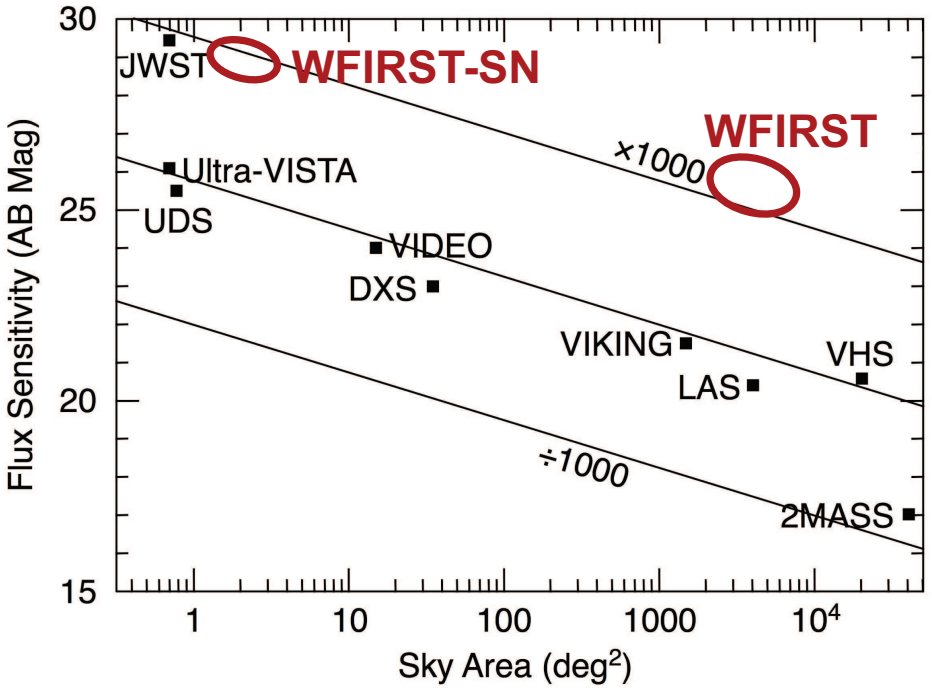
BUT general relativity may be incorrect:

$$\gamma \equiv \left(\frac{\ell n \overbrace{(d\ell n\delta / d\ell na)}^{perturbation\ growth\ rate}}{\ell n \Omega_m} \right)$$

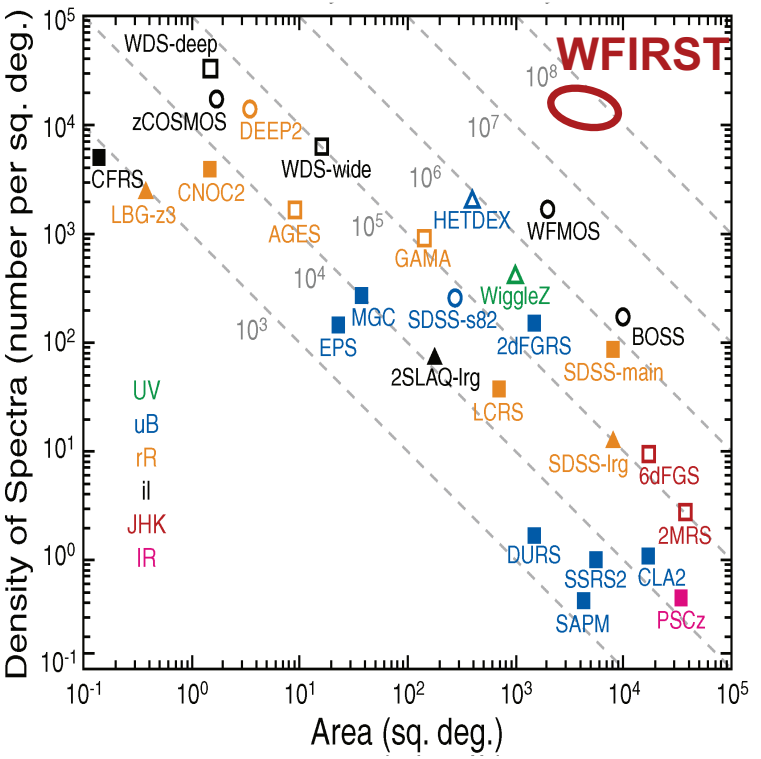
where $\gamma \approx 0.55$ for today's cosmology.

WFIRST NIR Surveys

NIR Imaging Surveys



NIR Redshift Surveys



WFIRST provides a factor of 100 improvement in IR surveys

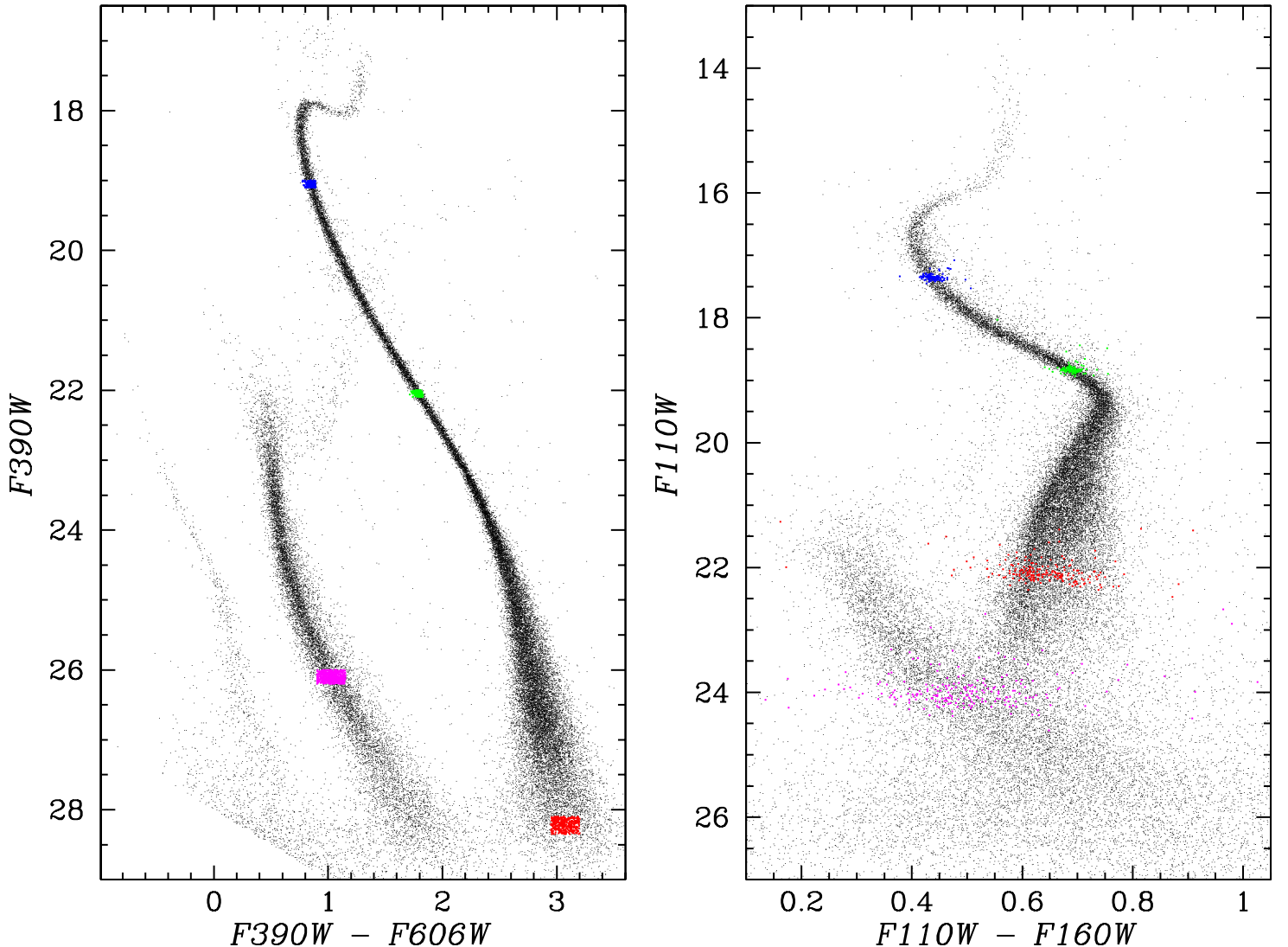
NOTIONAL GENERAL INVESTIGATOR PROGRAMS

Search for Kuiper Belt objects

Open cluster mass functions to $25M_{Jup}$

Stellar populations in nearby galaxy halos

Lower main sequence in globular clusters


F390W
F390W − F606W
F110W
F110W − F160W

STRAW MAN ALLOCATIONS

program	**DRM1**	**DRM2**
exoplanet microlensing	14.4 months	8.9 months
guest observers	6.1 months	3.6 months
supernovae	5.4 months	3.6 months
Galactic plane survey	5.3 months	3.4 months
high latitude survey[a]	14.6 months	9.9 months
redshift survey[b]	14.2 months	6.5 months
totals	5.0 years	3.0 years

[a] A.K.A. "weak lensing survey"

[b] A.K.A. "baryon acoustic oscillation survey"

http://www.arxiv.org/pdf/1208.4012

http://wfirst.gsfc.nasa.gov

WFIRST: an unobstructed 1.3-meter folded three mirror anastigmat with an HgCdTe focal plane

EUCLID: an axisymmetric 1.2-meter folded three mirror anastigmat with a (mostly) silicon focal plane

WFIRST Science Program

Complete the statistical census of planetary systems in the Galaxy
Determine the expansion history of the Universe and the growth history its largest structures
Perform a deep NIR survey of the Galactic and extra-Galactic sky
Execute a General Observer Program

Baseline Survey Characteristics[1]

Survey	Bandpass	Area (deg^2)	Depth[2]	Duration	Cadence
Exoplanet Microlensing	Y,W	3.38	n/a	1.2 years (72 days x 6)	W:15 min Y:12 hrs
Galactic Plane	Y,J,H,K	1240	25.1	0.45 years	n/a
High Latitude Survey (HLS)[3]	Y,J,H,K	3400	26.0	2.4 years	n/a
	GRS Prism	3400	1.0×10^{-16}		n/a
Supernova (SN) Survey	J,H,K	6.5 / 1.8 (wide/deep)	28.1 / 29.6	0.45 years (in 1.8 year interval)	5 days
	SNe Prism		27.6 / 28.5		

Payload

Telescope	Aperture 1.3m	Form Unobstructed TMA		Focal Ratio 15.9	Plate Scale 0.18"/pixel
Focal Plane	Detectors HgCdTe H2RG	Layout 9x4 [150 Mpix]		Detector Cutoff 2.5 μm	Active area 0.375 deg^2

Filters (μm)	Z	Y	J	H	K	W
	0.73-0.962	0.92-1.21	1.156-1.52	1.453-1.91	1.826-2.4	0.92-2.40

Prisms[4]	SN Ia		Galaxy Redshift Survey (GRS)	
	R=75	0.6-2.0 μm	R=600	1.5-2.4 μm

PROGRAM ALLOCATIONS

program	**DRM1**	**Euclid**
exoplanet microlensing	1.5 years	0 years
guest investigator	1.0 year	0 years
supernovae	0.5 year	0 years
BAO + weak lensing*	2.0 years	6.25 years

* imaging surveys proceed in parallel

Why is the WFIRST approach preferred for weak lensing?

weak lensing is the riskiest program:

$$\begin{pmatrix} \textbf{uncertainty in local} \\ \textbf{mean image ellipticity} \end{pmatrix} < \mathbf{0.0005}$$

1. **Progressive CCD charge transfer inefficiency elongates images.**
2. **CCDs allow only *one* very broad "riz" filter; galaxy shapes and PSF vary within bandpass.**
3. **Requirements on optics and jitter are specified relative to diffraction limit and are a factor of two less demanding in IR.**
4. **Unobscured design produces cleaner diffraction pattern.**
5. **Galaxies are less irregular in the red than in the blue.**
6. **Unless systematic ellipticity errors are within the requirement, additional area provides little or no benefit.**

Kocevski et al. http://www.arxiv.org/pdf/1109.2588

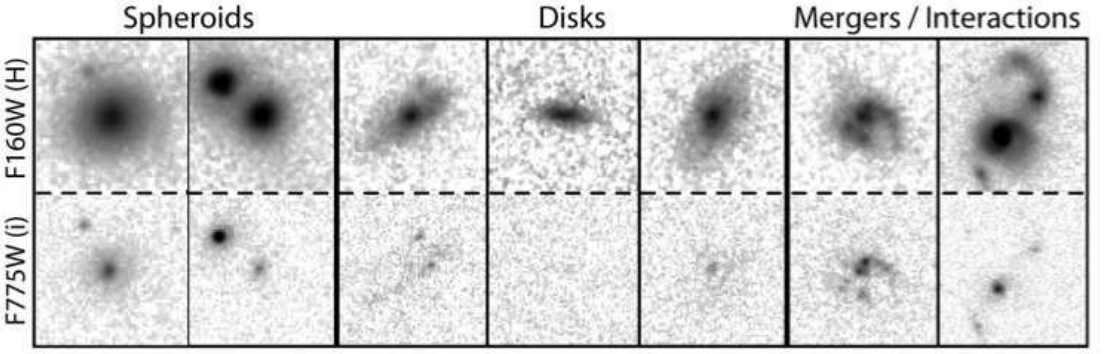
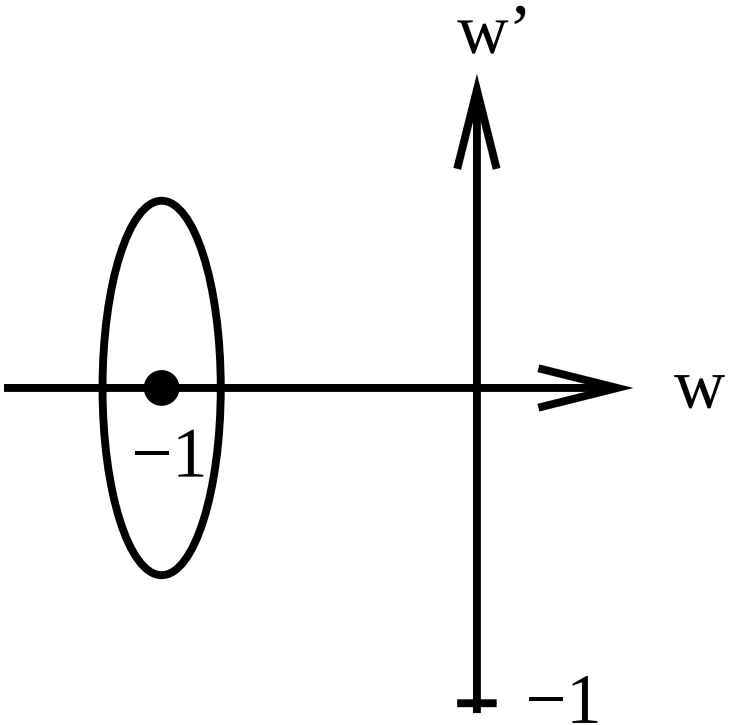


FIG. 3.— Examples of AGN host galaxies that were classified as having spheroid and disk morphologies, as well as two galaxies experiencing disruptive interactions. Thumbnails on the top row are WFC3/IR images taken in the F160W (H) band (rest-frame optical), while those on the bottom row are from ACS/WFC in the F775W (i) band (rest-frame ultraviolet). These images demonstrate that accurately classifying the morphology of these galaxies at $z \sim 2$ requires H-band imaging.


w'
w
−1
−1

Stage III + DRM1