TMT and Space-Based Survey Missions

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TMT Science Forum
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Outline

- Summary of space-based survey missions expected by/in the 2020's:
  - WISE, eROSITA, Euclid, WFIRST-AFTA
  - (omitting Kepler and GAIA)

- Summary of other space-based survey mission concepts also in play:
  - NEOCam, WISH, WFXT
  - (omitting CASTOR, etc...)

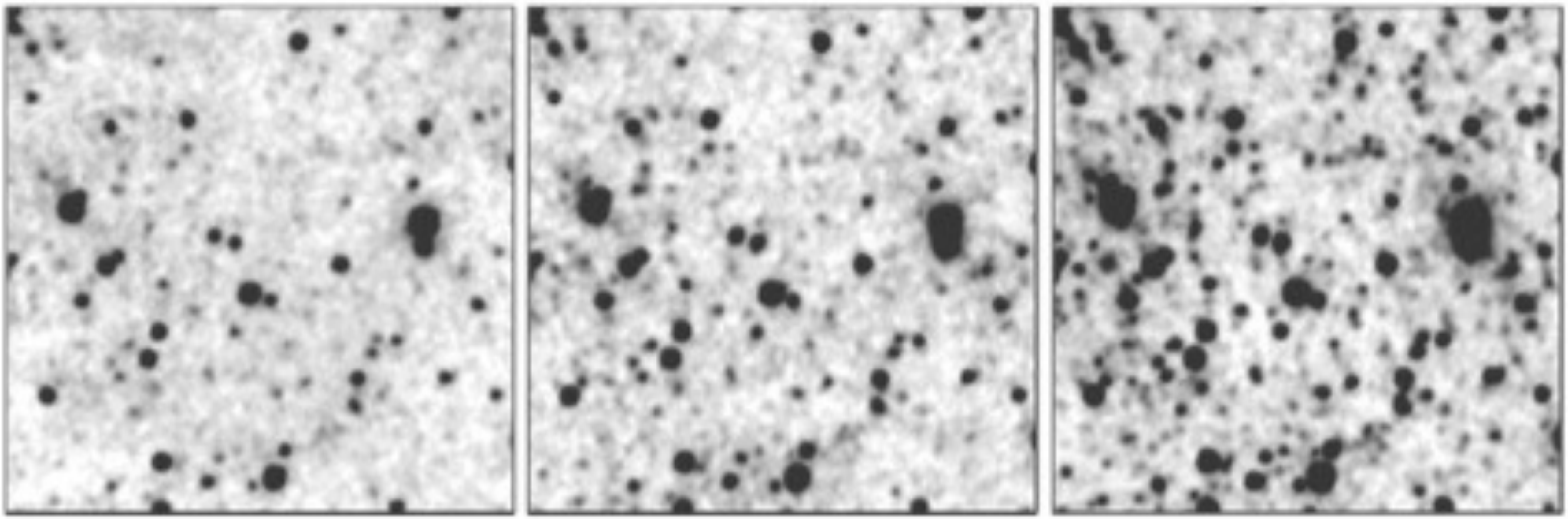
- A few science highlights for TMT / space-based survey mission synergies:
  - z>10
  - z(spec) to train z(phot) for Euclid/WFIRST
  - strong lenses from Euclid/WFIRST
  - local dwarf galaxies
  - WFIRST microlensing follow-up

WISE

Wide-field Infrared Survey Explorer

NASA MidEX
launch date: **2009**
4-band all-sky mid-IR survey (3.4 - 22 μm)
extended mission: NEOWISE/MaxWISE
all-sky survey from LEO; deeper at poles
"IRAS on steroids"

WISE



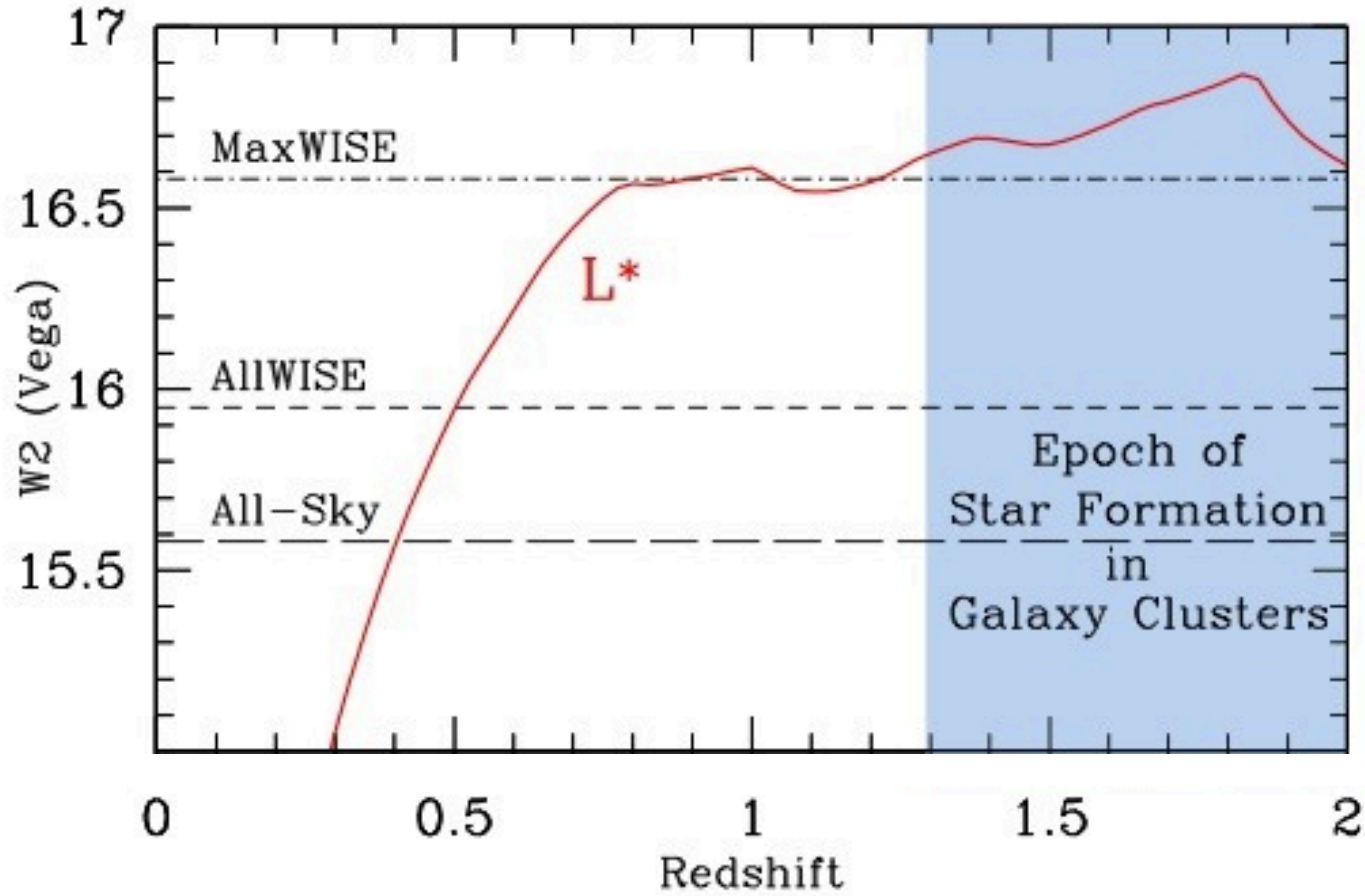
WISE
12 exp.

AllWISE
24 exp.

MaxWISE
96 exp.

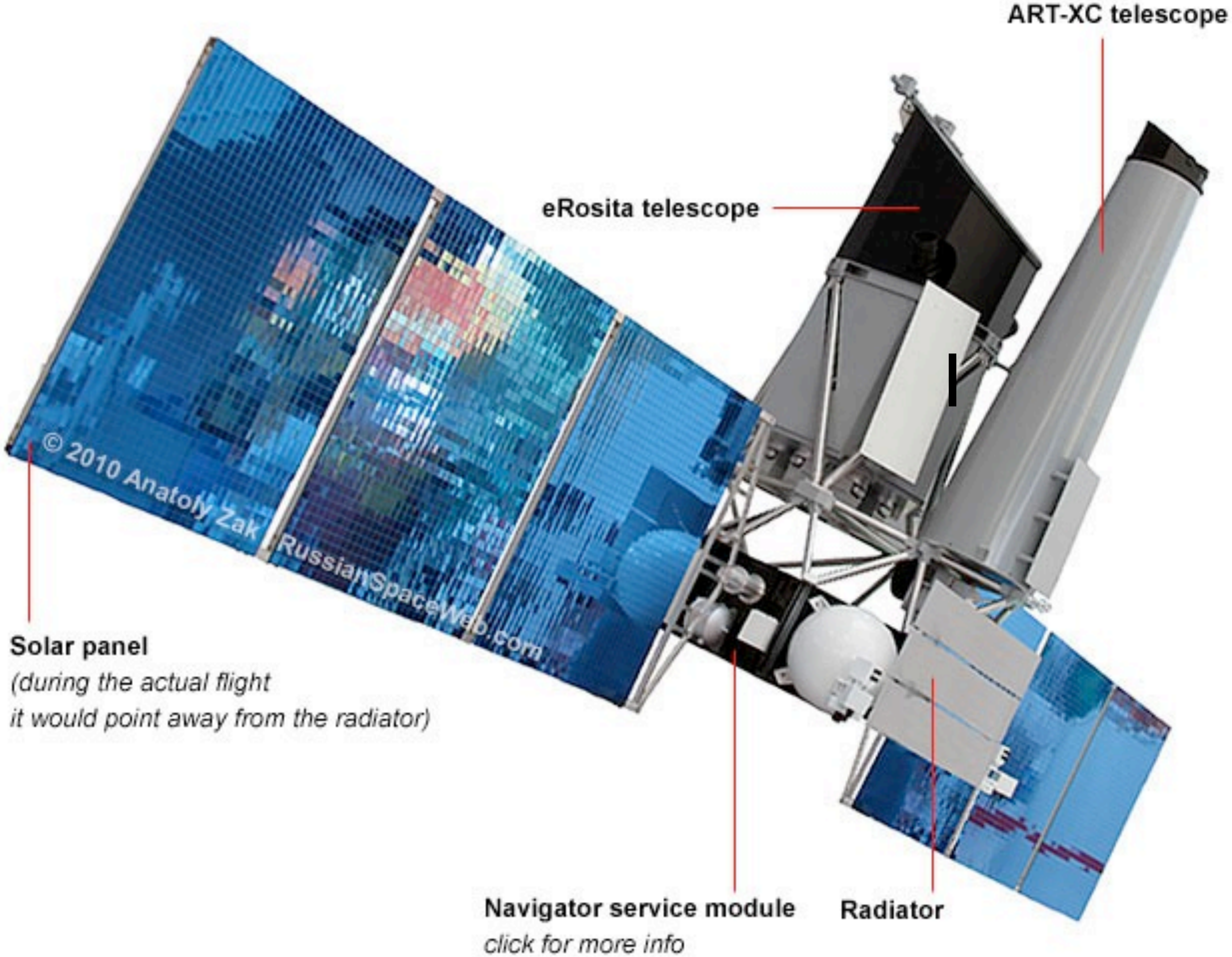
- NEOWISE has been surveying the sky to find near-Earth objects (NEOs) and asteroids since Dec. 2013; three additional years of survey planned (funded by NASA Solar System Div.)
- 8x the exposure time of WISE, 4x the exposure time of AllWISE -- but just in the the two bluer (more sensitive) passbands

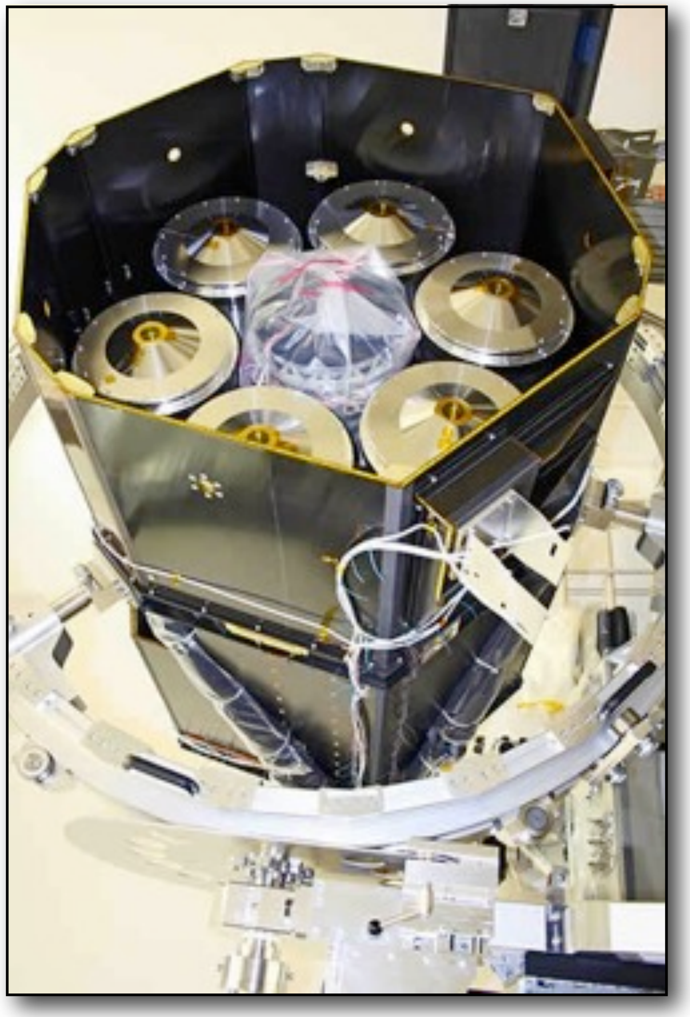
WISE



- extremely good at normal galaxies too -- negative k-correction makes MaxWISE sensitive to normal L* galaxies out to z~2+
- very good for galaxy clusters as well

eROSITA / SRG



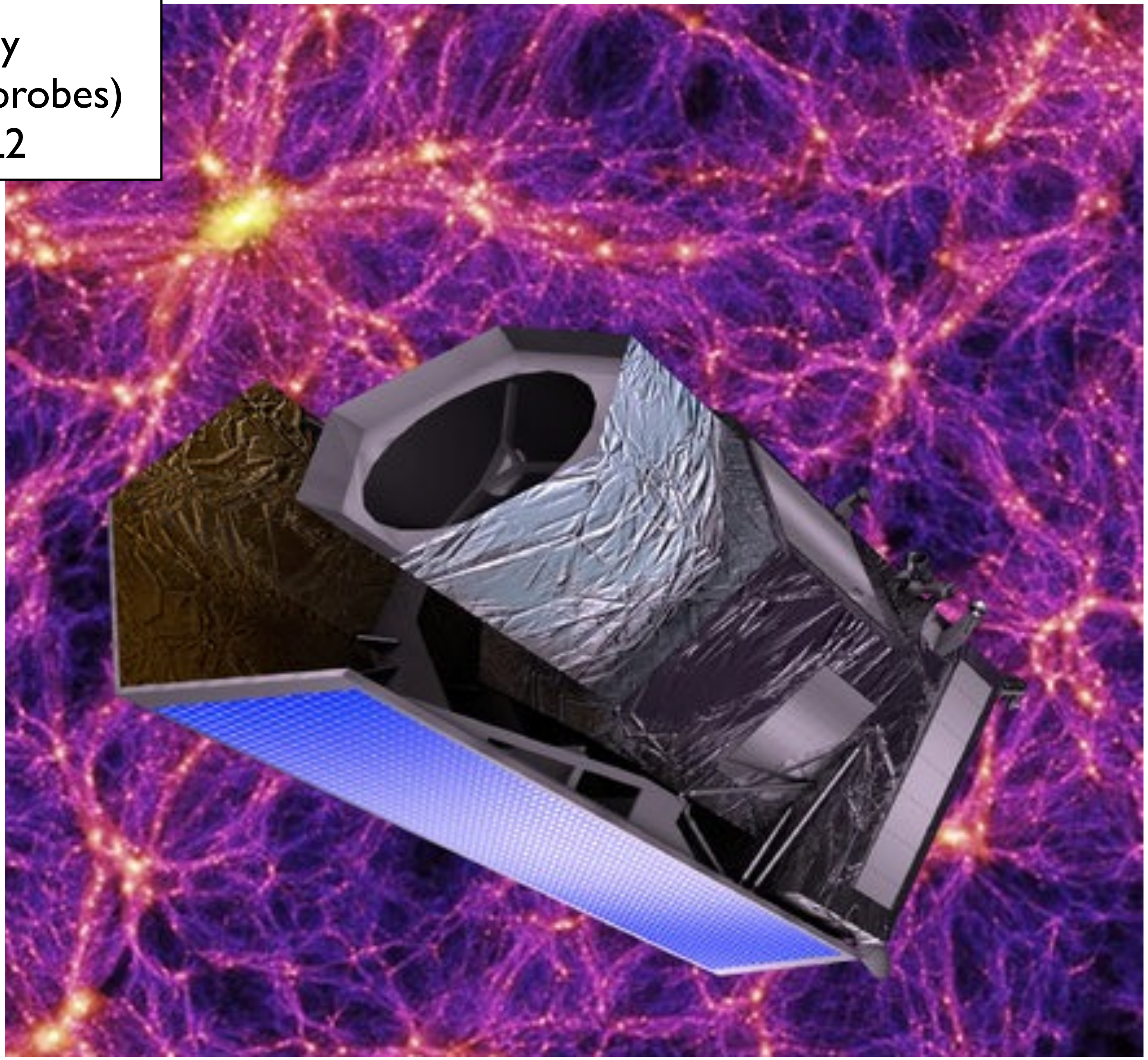


German-Russian project
launch date: **2016**
all-sky 0.5-10 keV survey from L2
deeper at poles
"ROSAT on steroids"

eROSITA science will be discussed in P. Fabbiano's talk

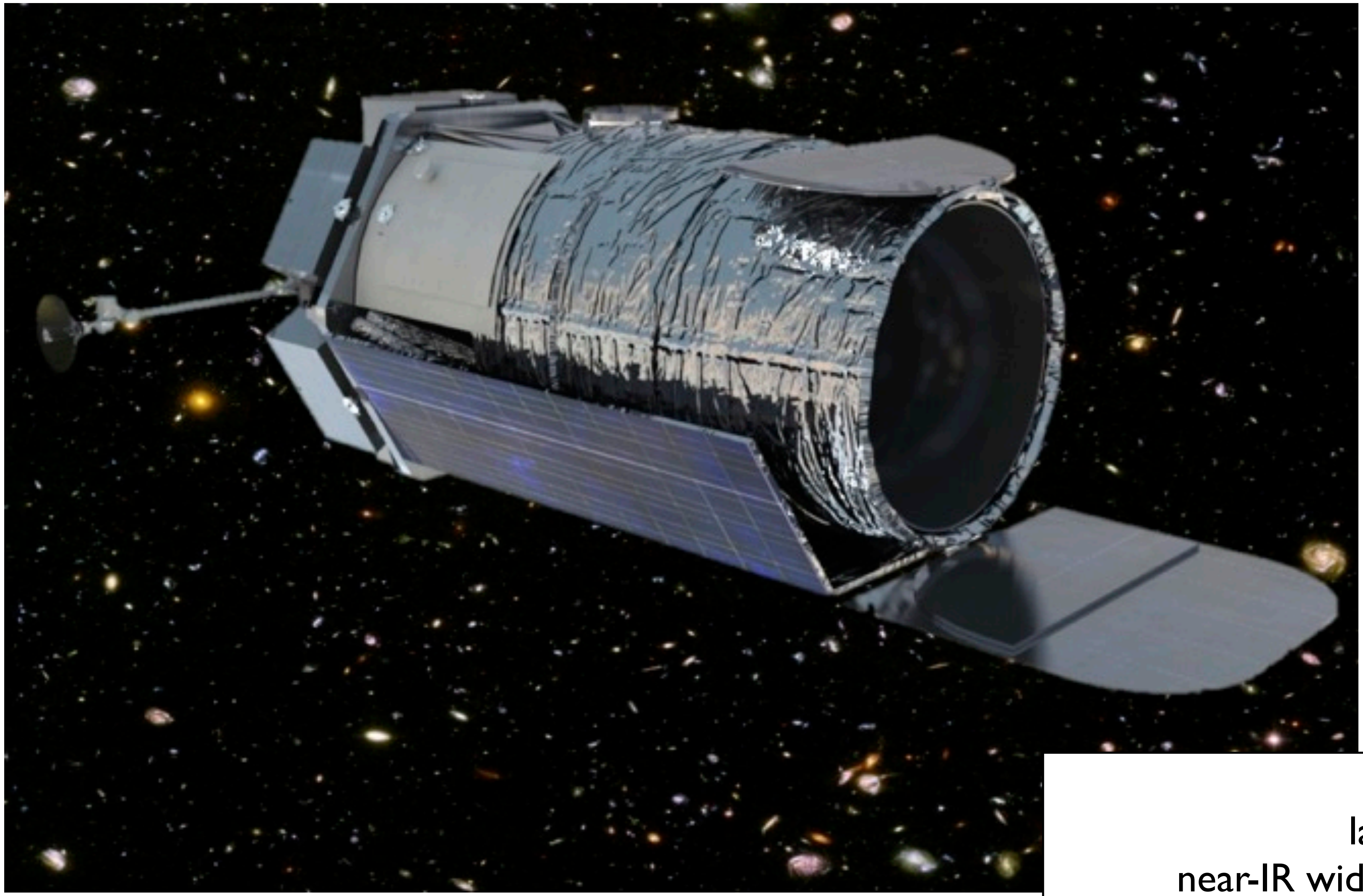
Euclid

ESA M-Class
launch date: **2020**
optical + near-IR wide-area survey
primary science: cosmology (multiple probes)
6-yr. survey of 15,000 deg^2 from L2



WFIRST-AFTA

Wide-field Infrared Space Telescope - Astrophysics Focused Telescope Asset

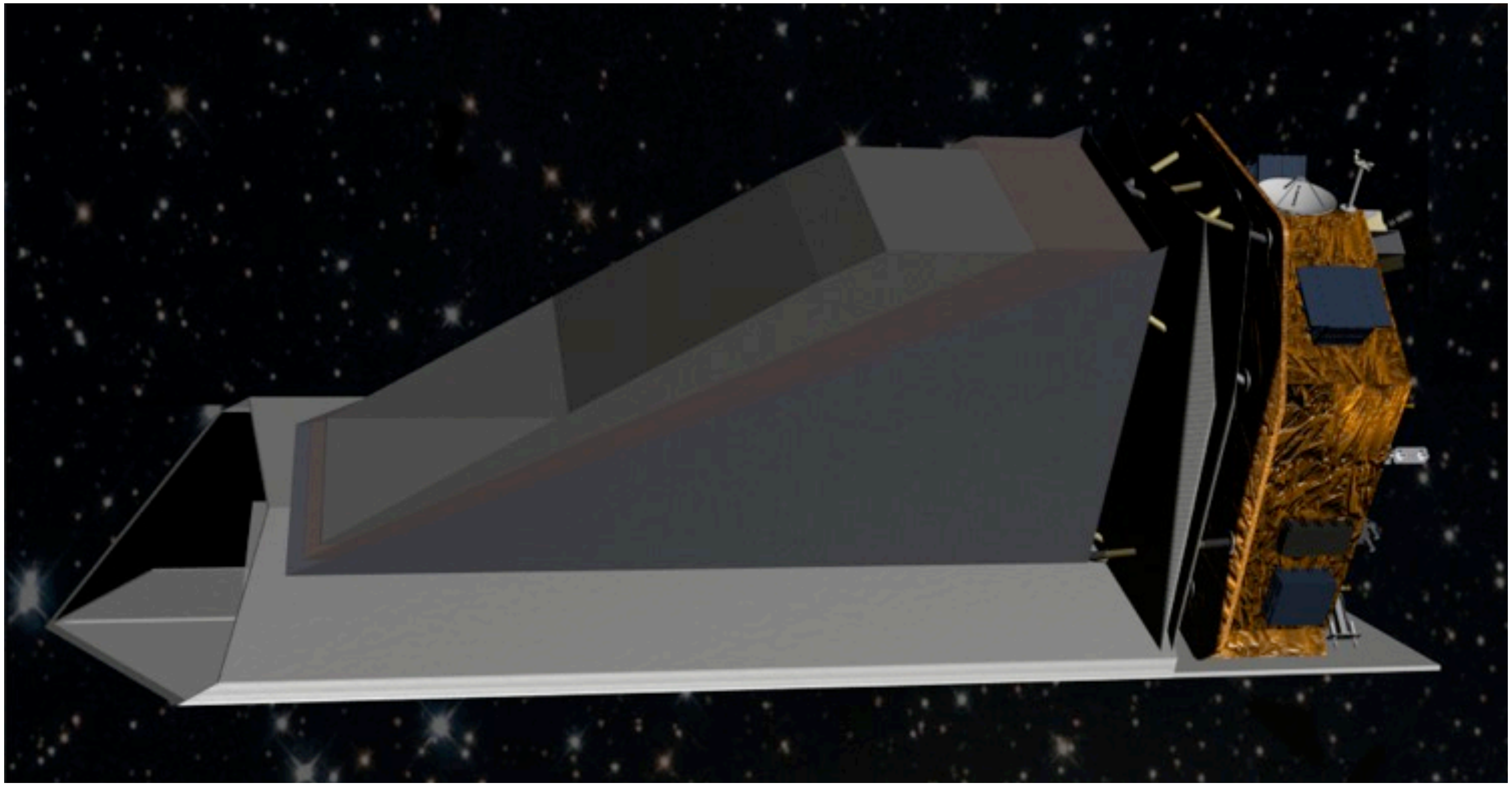


NASA Flagship
launch date: **2024 (?)**
near-IR wide-area camera (+ coronagraph?)
multiple science objectives:
- cosmology (multiple probes)
- microlensing survey of Galactic bulge
- infrared survey science
- exoplanet coronography
- 25% of time for guest observers

NEOCam

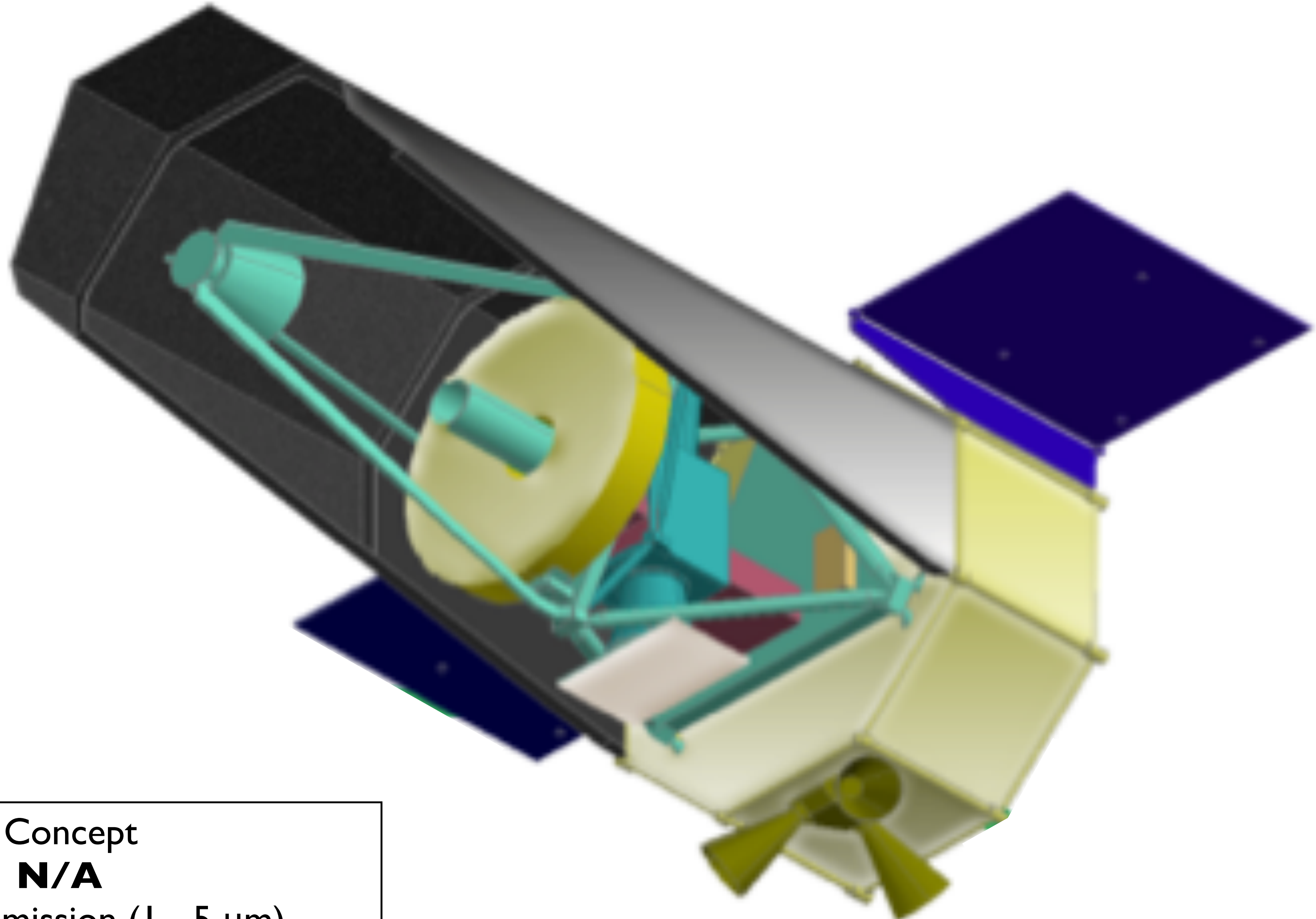
Near-Earth Object Camera

NASA Discovery Mission Concept
launch date: **N/A**
wide-field thermal infrared camera
received technology development funding from NASA
primary science: NEOs + asteroids
(proposing to NASA Solar System Div., but obviously exciting for Astrophysics)



WISH

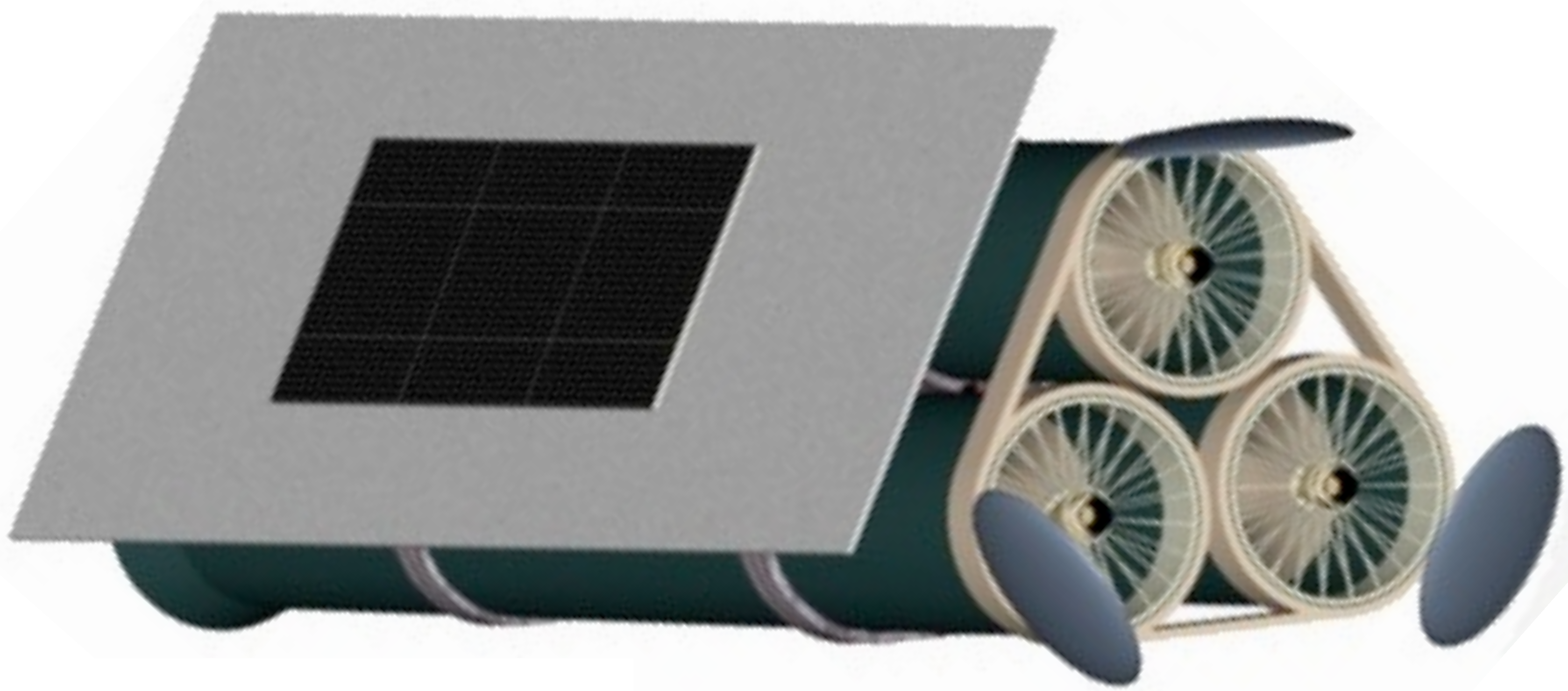
Wide-field Imaging
Surveyor for High-redshift



JAXA Mission Concept
launch date: **N/A**
1.5 m mirror, cryogenic mission (1 - 5 μm)
very deep ~100 deg^2 survey (AB ~ 28)

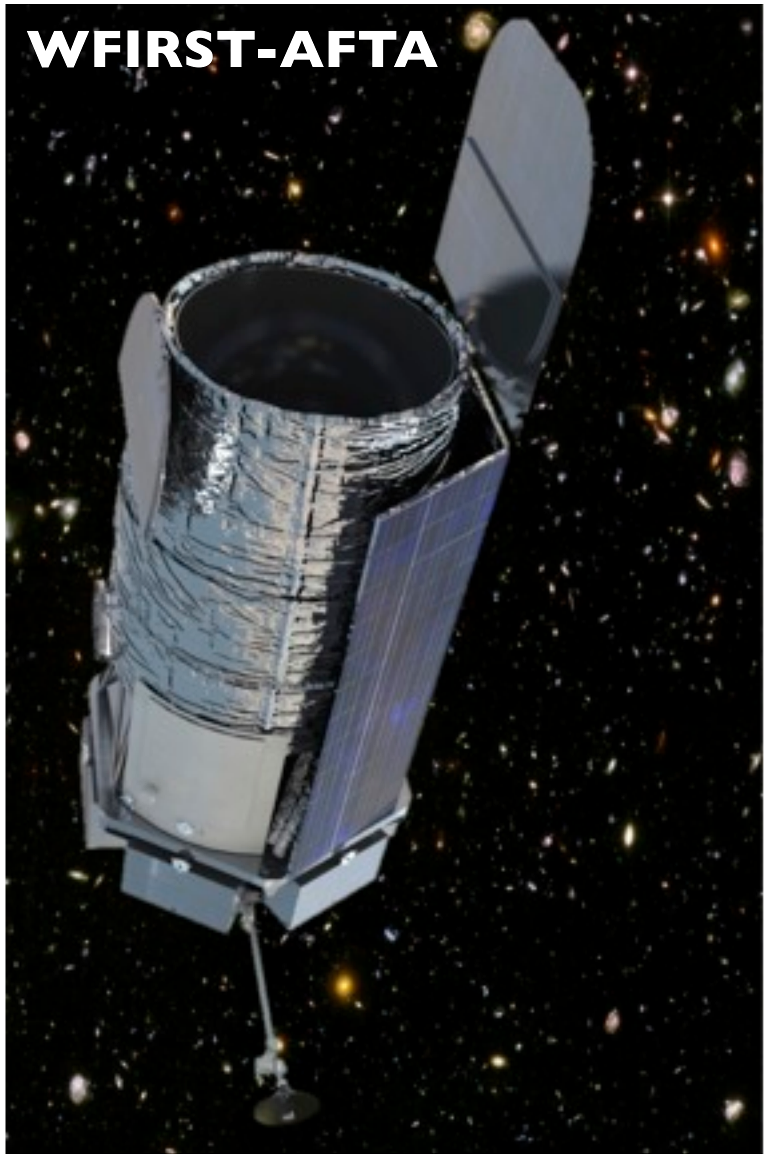
WFXT

Wide-field X-ray Telescope

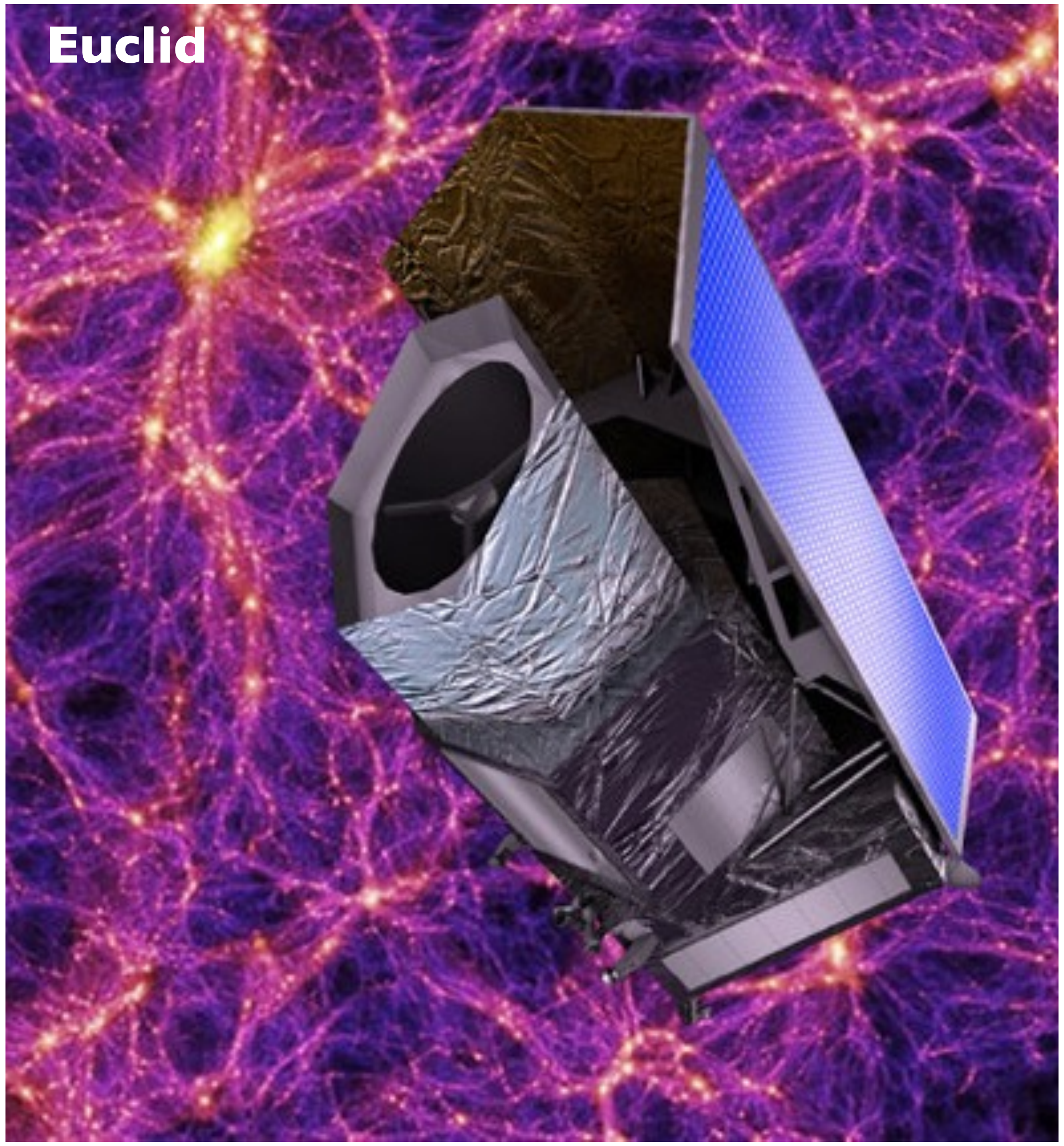


NASA Probe-Class Mission Concept
launch date: **N/A**
"eROSITA on steroids"
5 arcsec PSF
wide-area (3000 deg^2) survey + deeper 100 deg^2 survey
+ 2 years guest observer program

WFIRST-AFTA / Euclid comparison

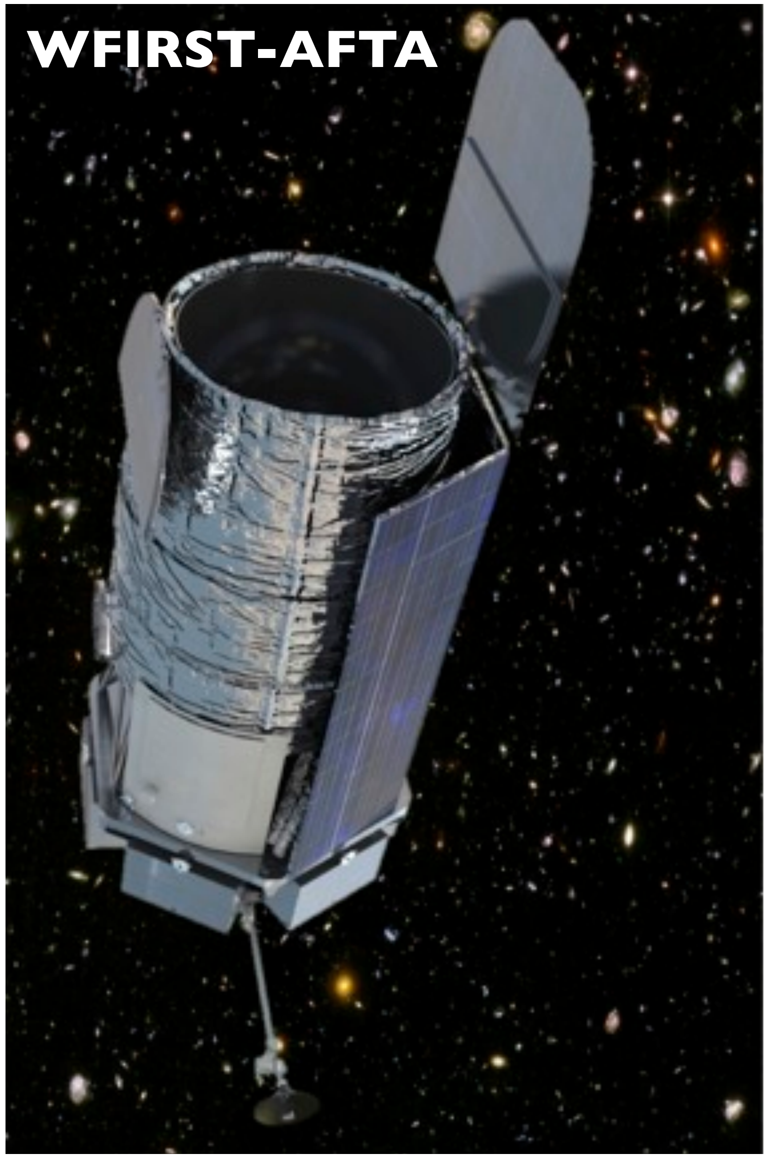


2.4 m TMA ("AFTA")
18 H4RG detectors
0.7 - 2.0 micron bandpass
0.28 sq. deg FoV
4 filter imaging; grism + IFU spectroscopy
6 yr. baseline mission

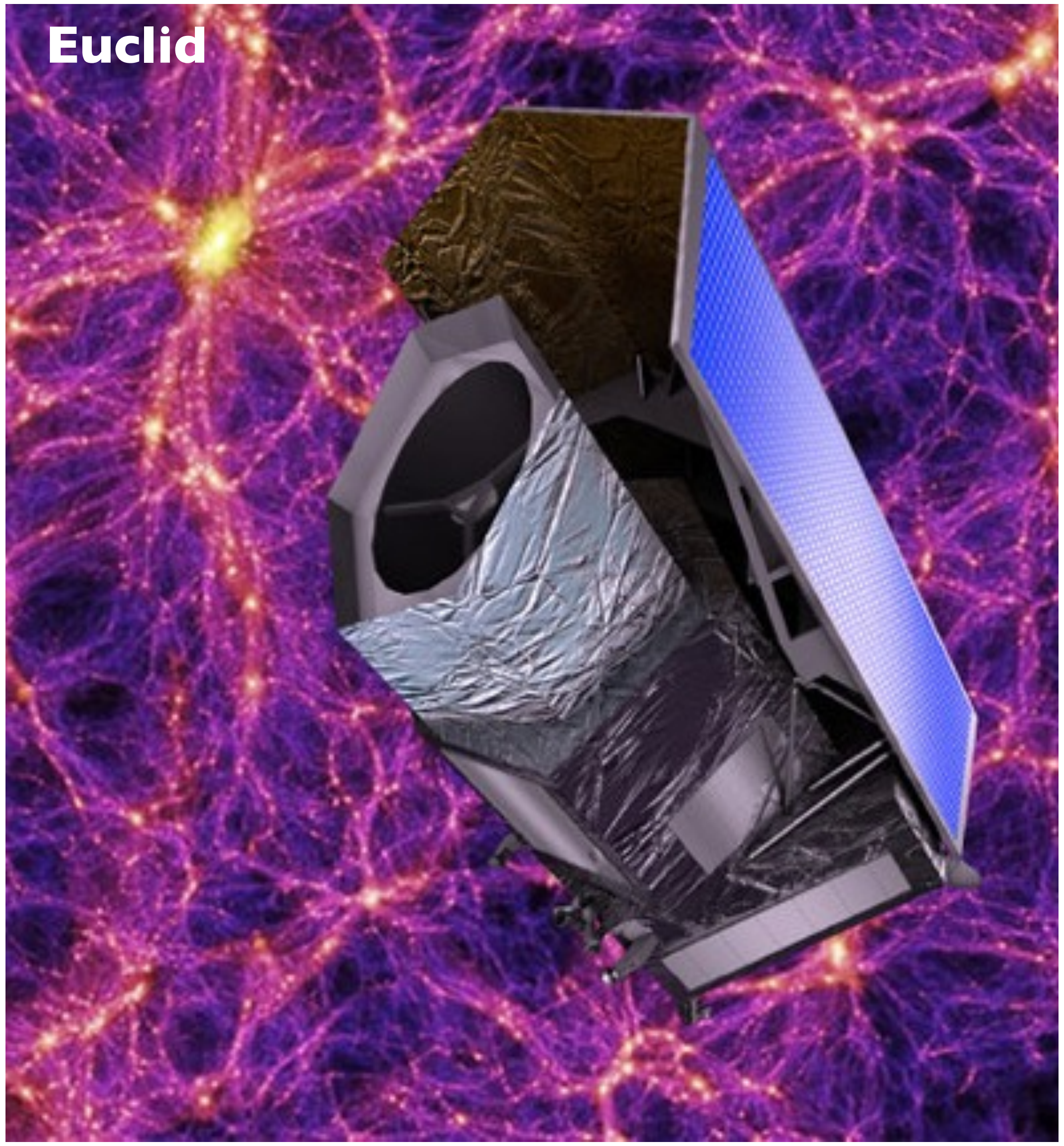


1.2 m TMA
36 4kx4k CCDs + 16 H2RG detectors
0.55 - 2.0 micron bandpass
0.55 sq. deg FoV
4 filter imaging, grism spectroscopy
6 yr. baseline mission

WFIRST-AFTA / Euclid comparison

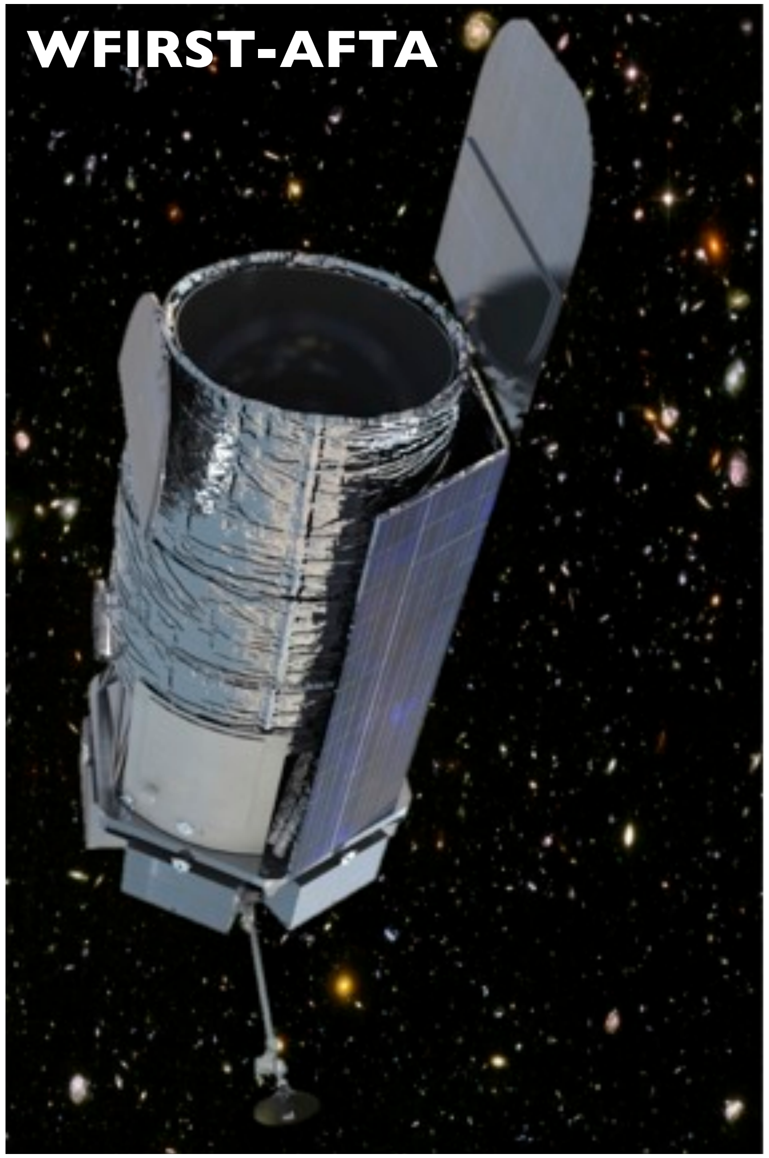


0.11" / pix
wide survey: 2400 sq. deg., ~27 mag AB
R~600 grism + R~100 IFU
grism survey depth: 3e-17 erg/cm2/s (3.5σ)

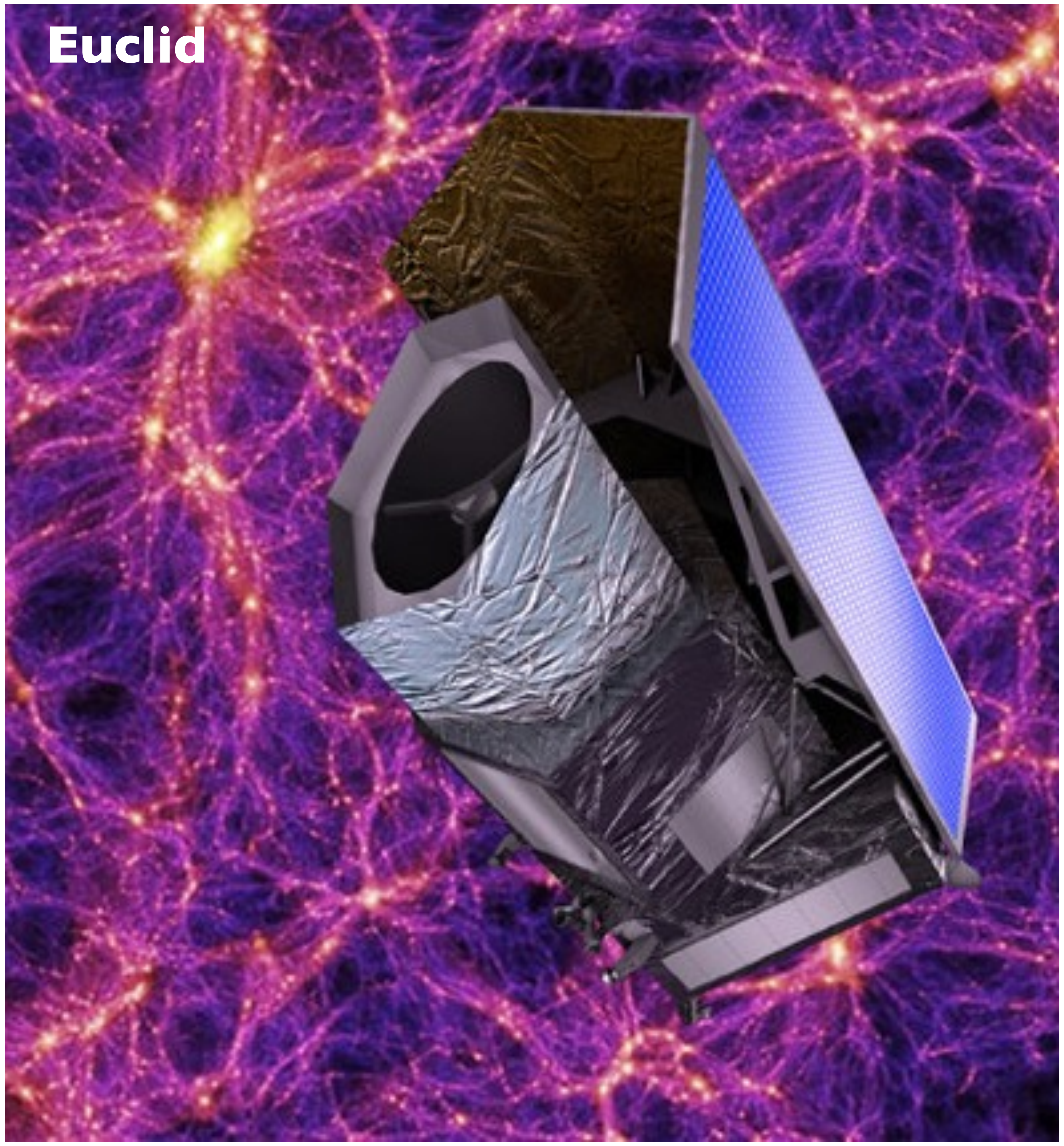


0.10" / pix (optical); 0.30" / pix (near-IR)
wide survey: 15,000 sq. deg., ~24 mag AB
R~250 grism
grism survey depth: 3e-16 erg/cm2/s (3.5σ)

WFIRST-AFTA / Euclid comparison

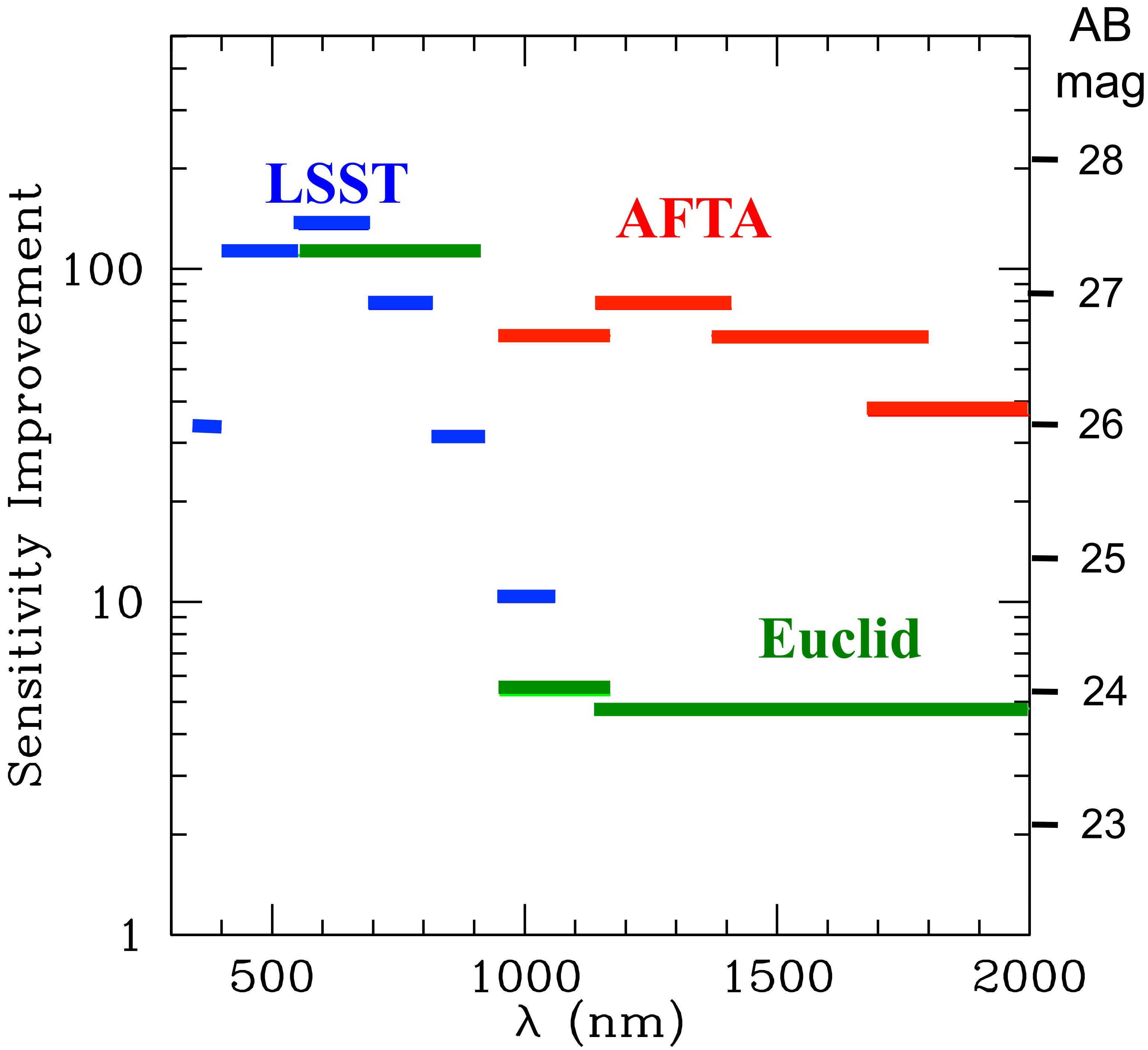


cosmology
infrared survey science
microlensing exoplanet survey
guest observer (GO) program: 25% of time



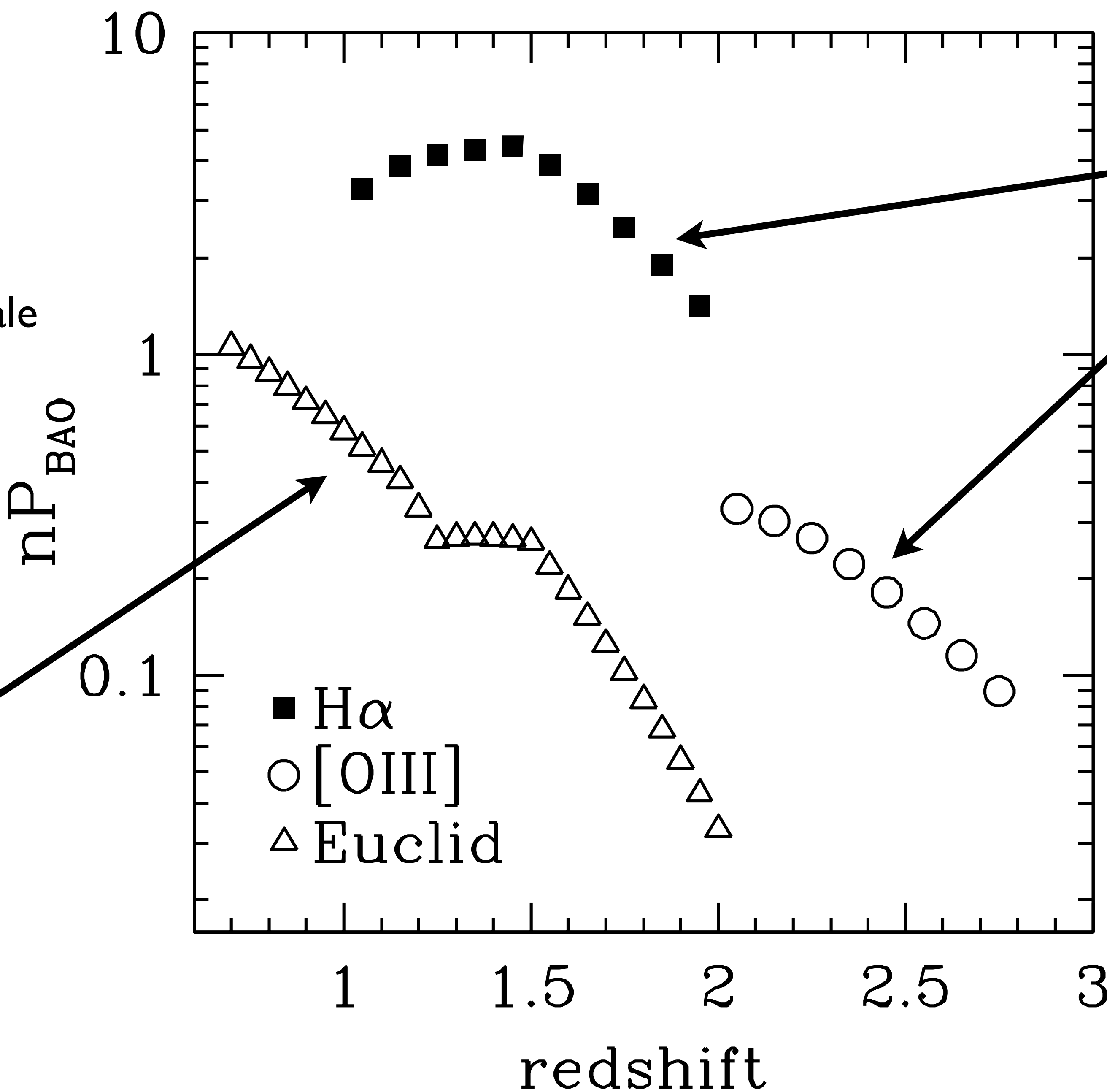
cosmology
optical + infrared survey science
(no microlensing survey or GO program)

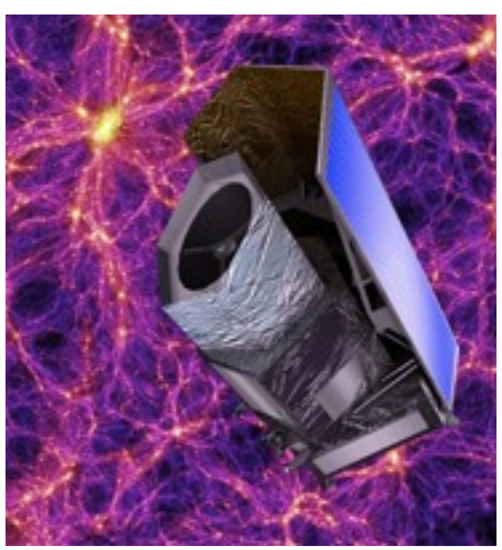
WFIRST-AFTA / Euclid comparison



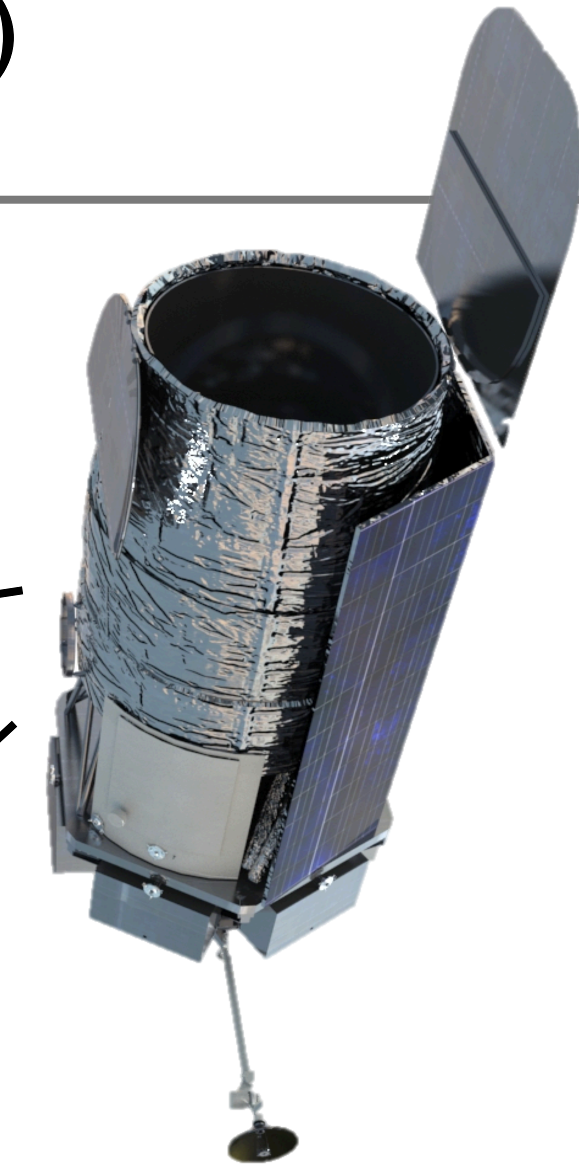
baryon acoustic oscillations (BAO)

number density of
galaxies at BAO scale





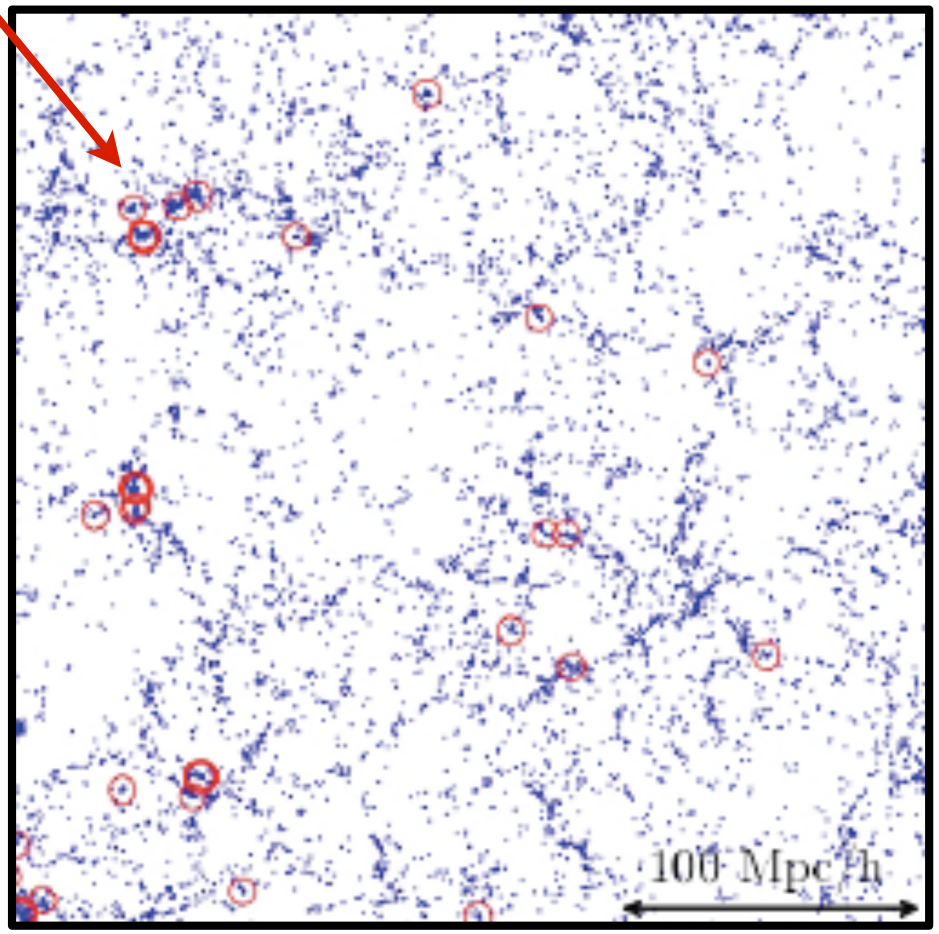
Euclid



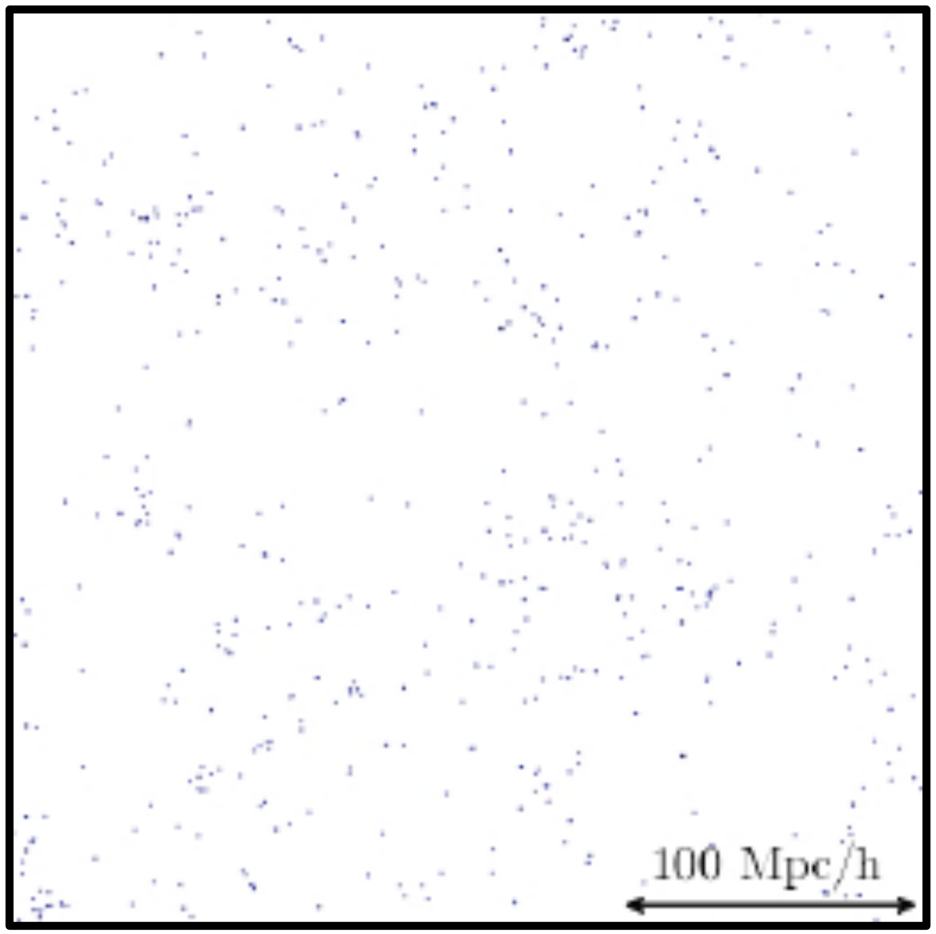
WFIRST-AFTA

BAO - spectroscopic sample comparison

clusters:
>5e13 M(sun)
>1e14 M(sun)



WFIRST-AFTA wide survey
2400 sq. deg.
12,600 gal/deg^2



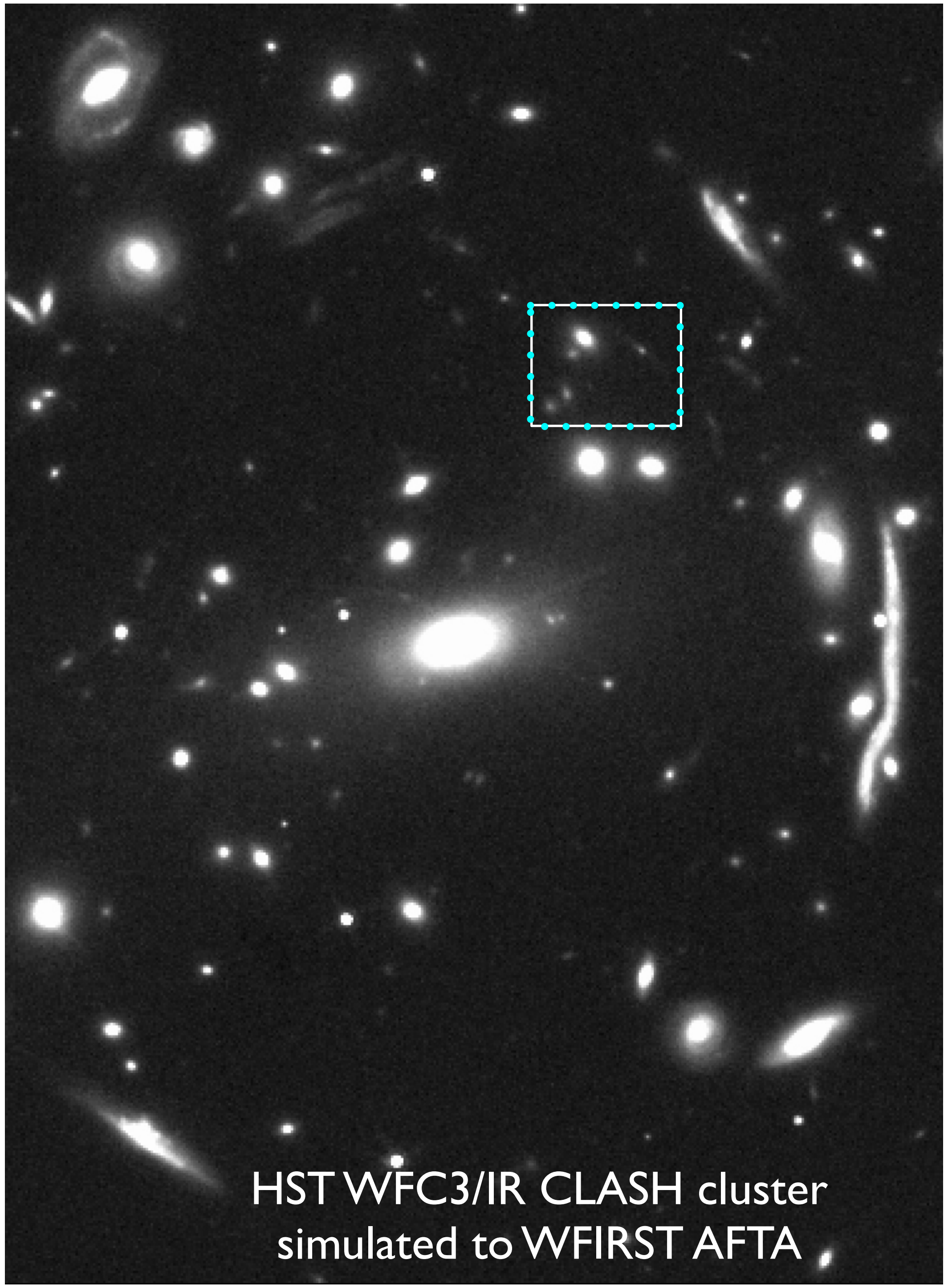
Euclid wide survey
15,000 sq. deg.
1700 gal/deg^2

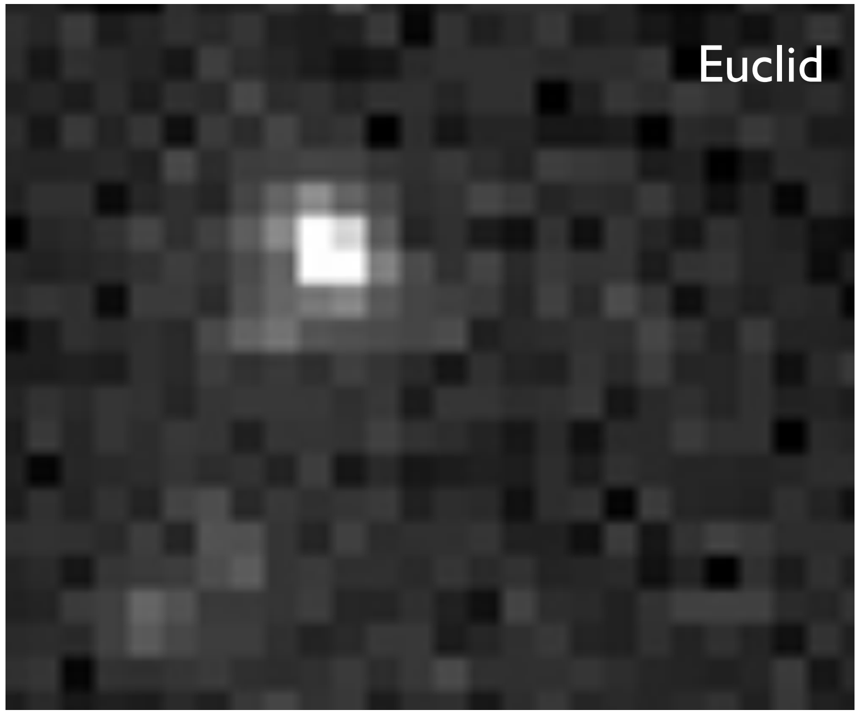
supernovae: high-quality IFU spectra of 2700 SNe

no supernova program

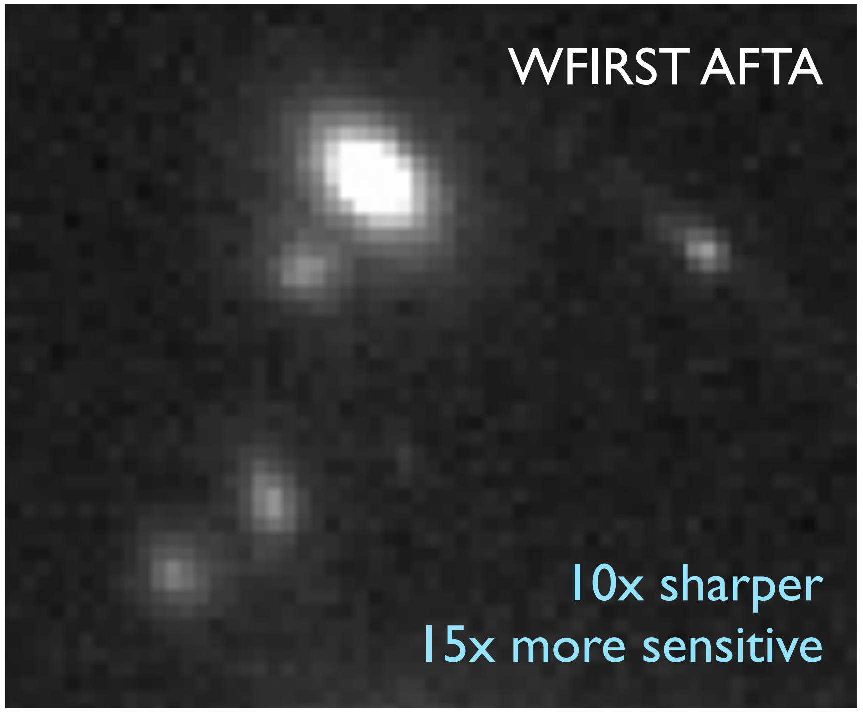
baryon acoustic oscillation (BAO) grism program
extends to z~3

IR imaging / strong lensing reconstruction



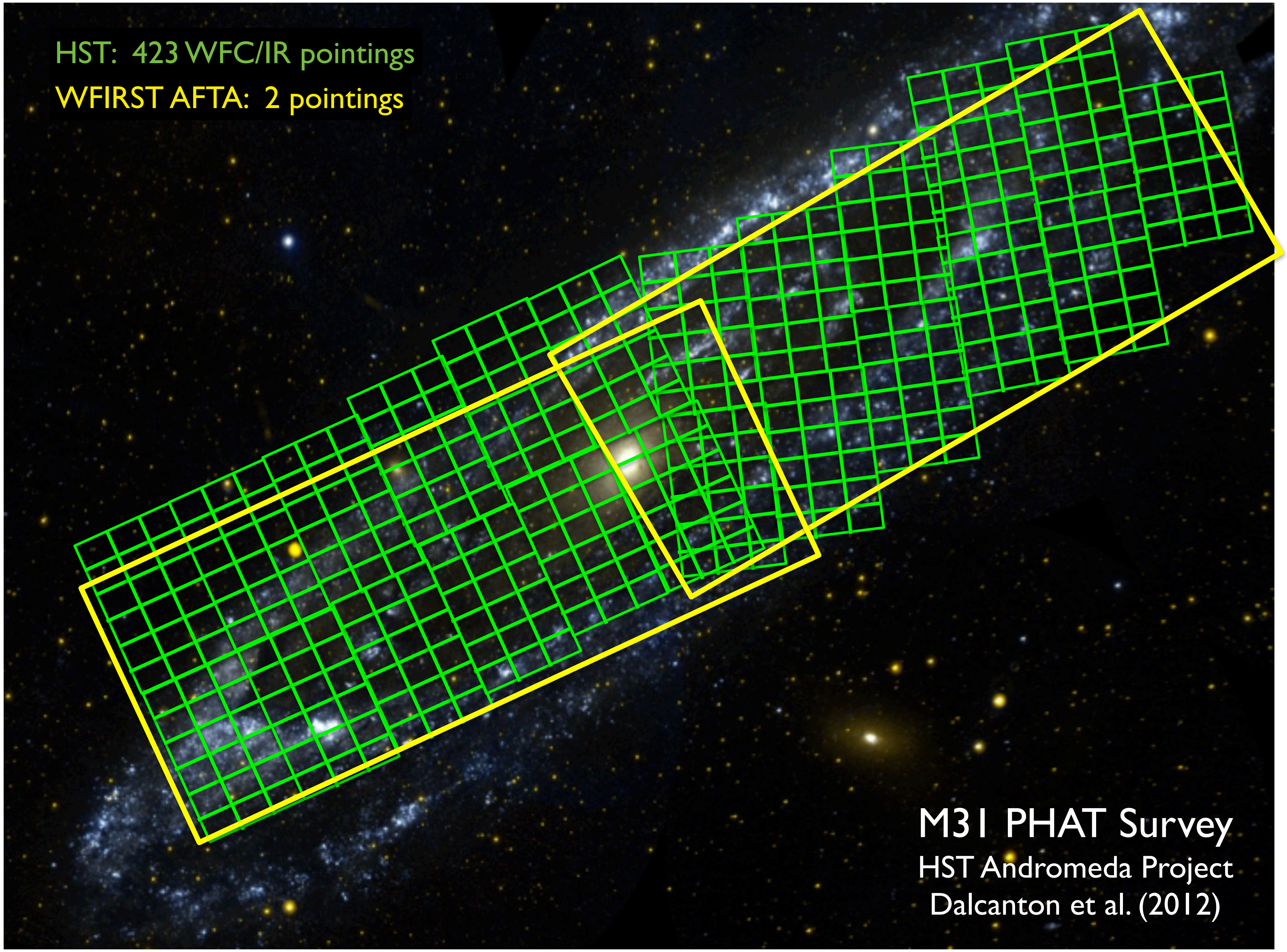


0.30” pix
(near-IR)



0.11” pix

WFIRST-AFTA vs. Hubble



Science Case #1: z>10 galaxies and quasars

Survey	Area (deg^2)	Depth (5-sigma, AB)	z>7 QSO's	z>10 QSO's
UKIDSS-LAS	4000	Ks=20.3	8	-
VISTA-VHS	20,000	H=20.6	40	-
VISTA-VIKING	1500	H=21.5	11	-
VISTA-VIDEO	12	H=24.0	1	-
Euclid, wide	15,000	H=24.0	1358	22
Euclid, deep	40	H=26.0	14	-
WFIRST DRM1, HLS	2800 / yr	K=26.1	1134 / yr	22 / yr
WFIRST-AFTA	1080 / yr	H=27.1	670 / yr	13 / yr

WFIRST will revolutionize studies of cosmic dawn

- measure the first epoch of black hole formation in the universe
- probe earliest phases of structure formation
- unique probes of the intergalactic medium
- probe the epoch(s) of reionization
- WFIRST will identify the rarest, most distant luminous quasars – NOT JWST science!

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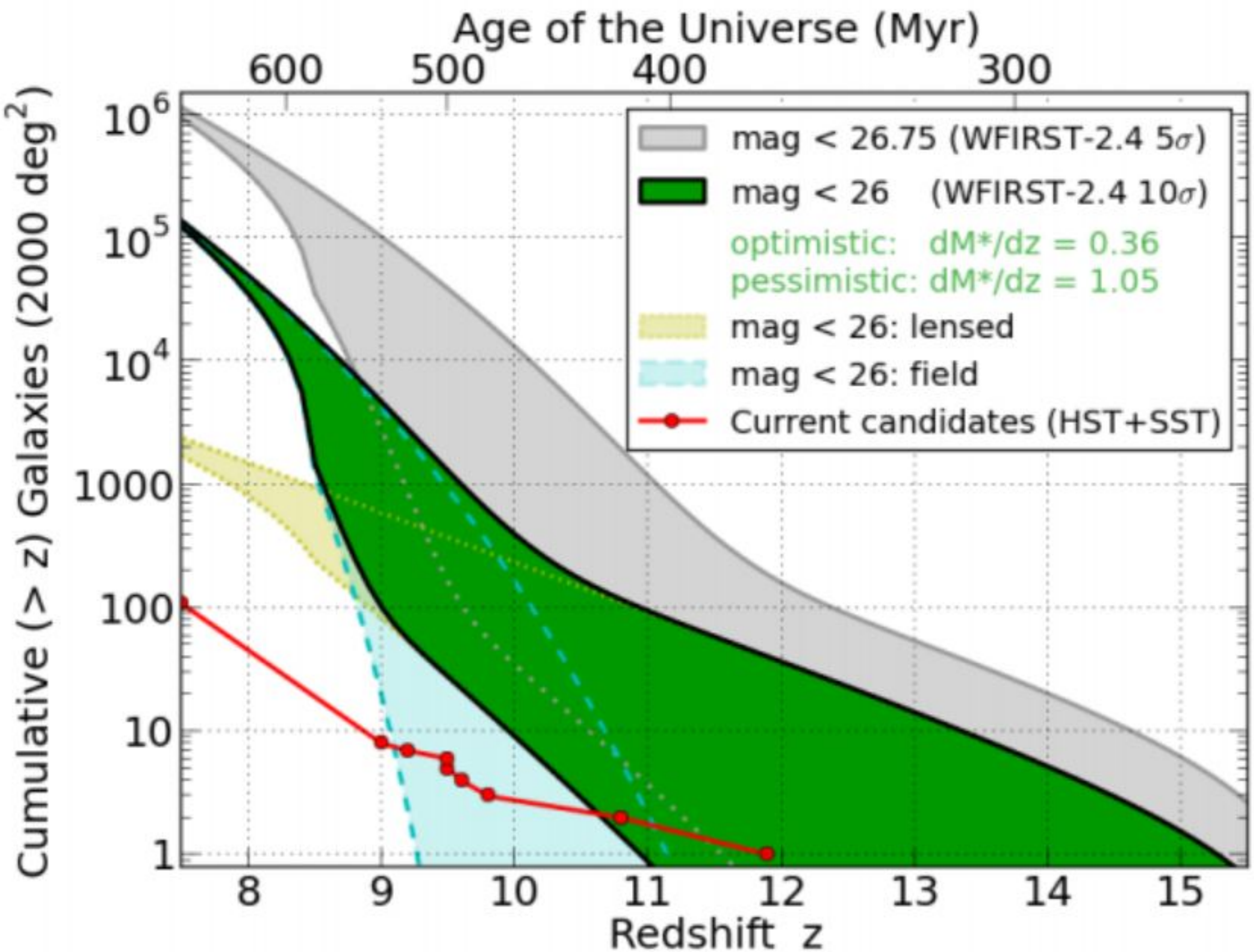
TMT essential for spectroscopic confirmation and studies

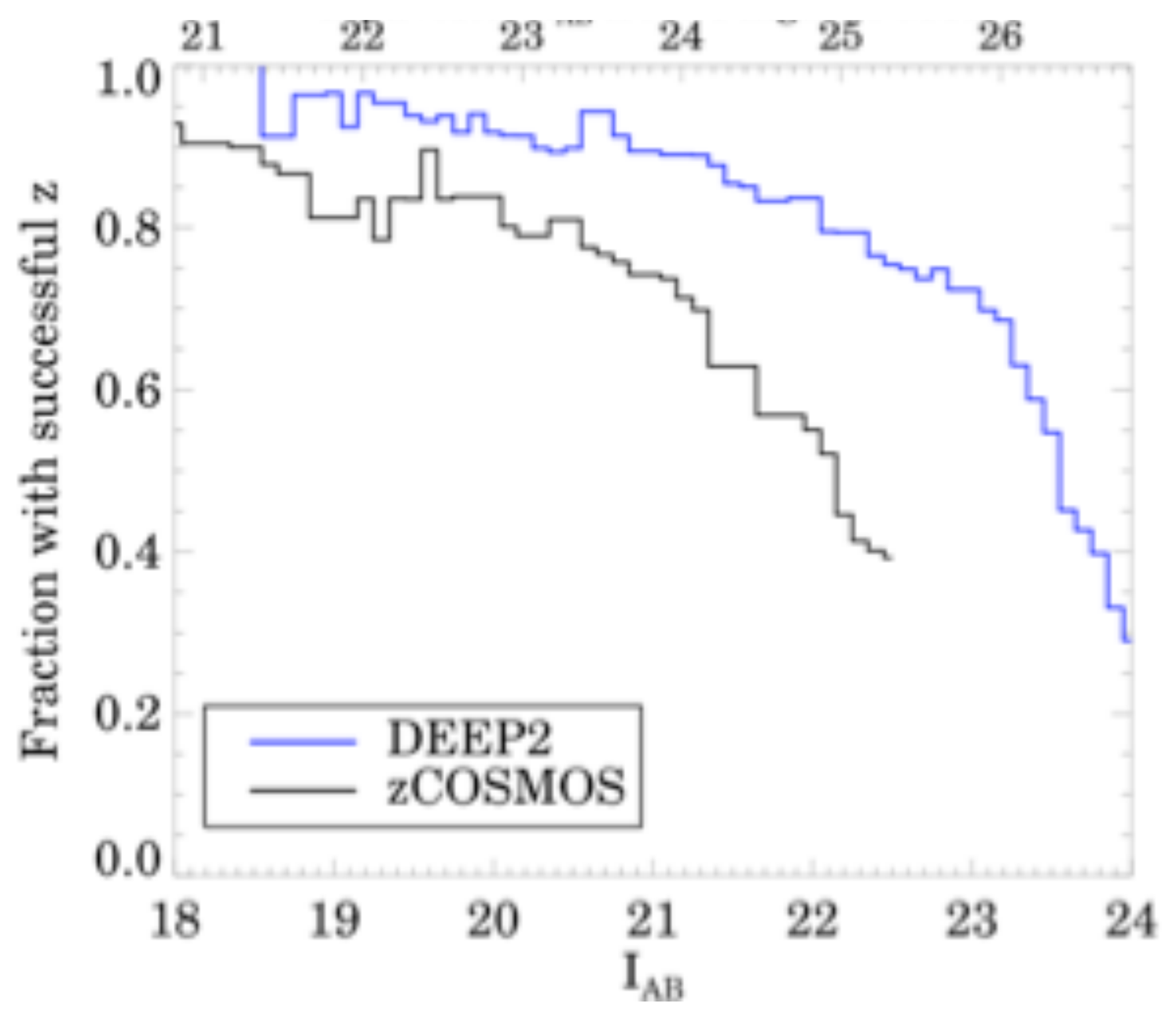
Science Case #1: z>10 galaxies and quasars



100x increase in the number of z>7 galaxies, reaching out to z~15
TMT essential for spectroscopic confirmation and studies

Science Case #2: z(spec) to train z(phot) for cosmology

- Success of Euclid and WFIRST-AFTA weak lensing cosmological probe is predicated on accurate, unbiased photometric redshifts
- Area of extensive work for Euclid already; starting now for WFIRST-AFTA
- "Machine learning" algorithms currently seem most promising, but require spectroscopic redshifts of sources with similar properties to photometric sample

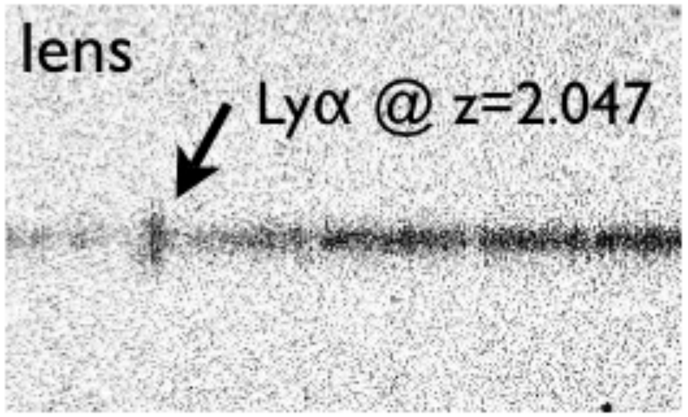


Science Case #3: strong gravitational lenses

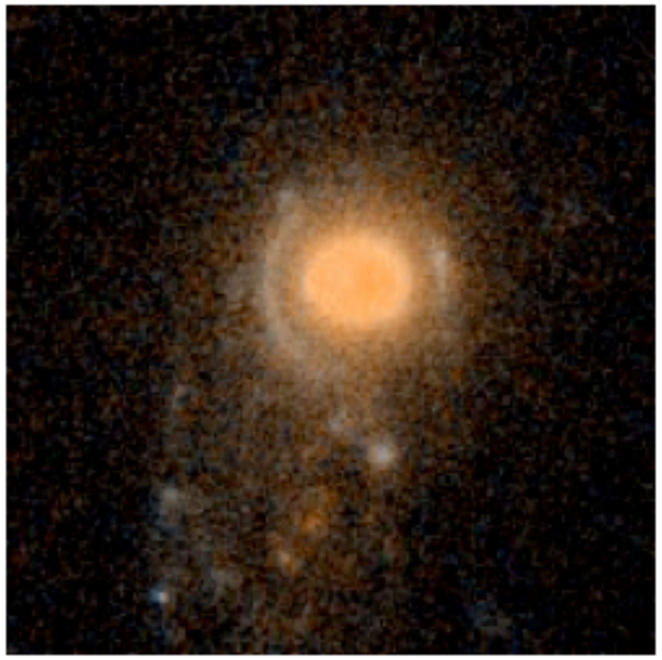
Euclid and WFIRST will find huge numbers (~100x increase) of strong gravitational lenses

- teaches us about the mass and mass distribution of the lensing galaxy
- provides magnified view of background galaxy
- secondary cosmological probe from lens statistics ("lens redshift test")
- rare "compound" lenses
- rare lensing quasars (instead of lensed quasars): precise host galaxy masses to study evolution of M-sigma rel'n
- rare lensed supernovae useful as cosmological probe
- combine strong + weak lensing analyses of clusters to study dark matter distribution

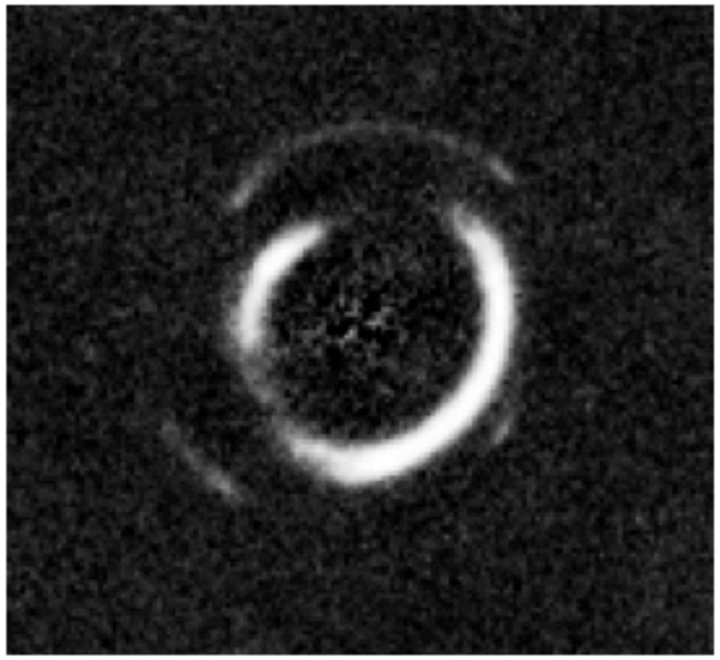
TMT essential for getting lens redshifts and higher precision lens imaging



slitless spectra lens

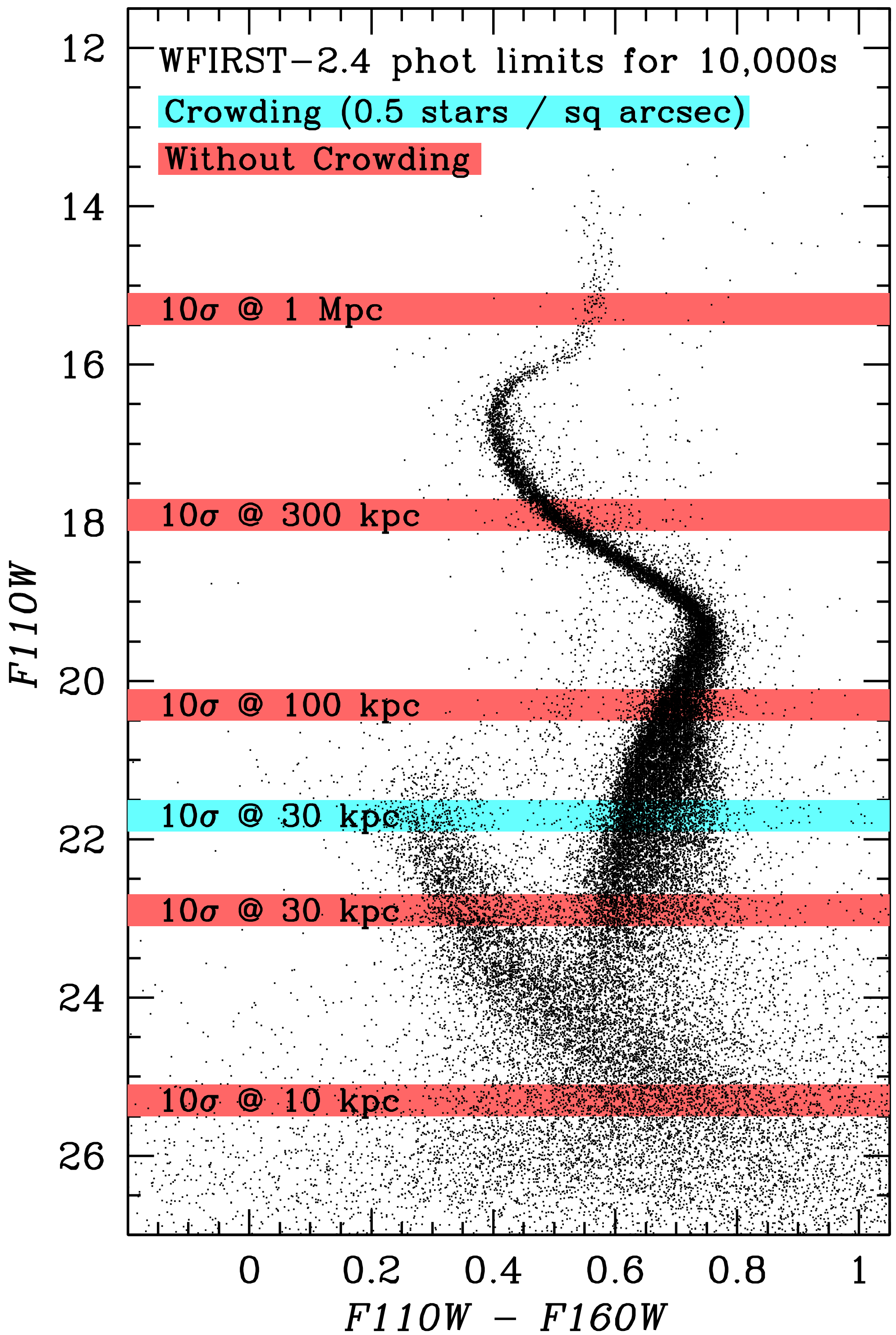


SLACS lens



compound lens

Science Case #4: Local Group dwarf galaxies

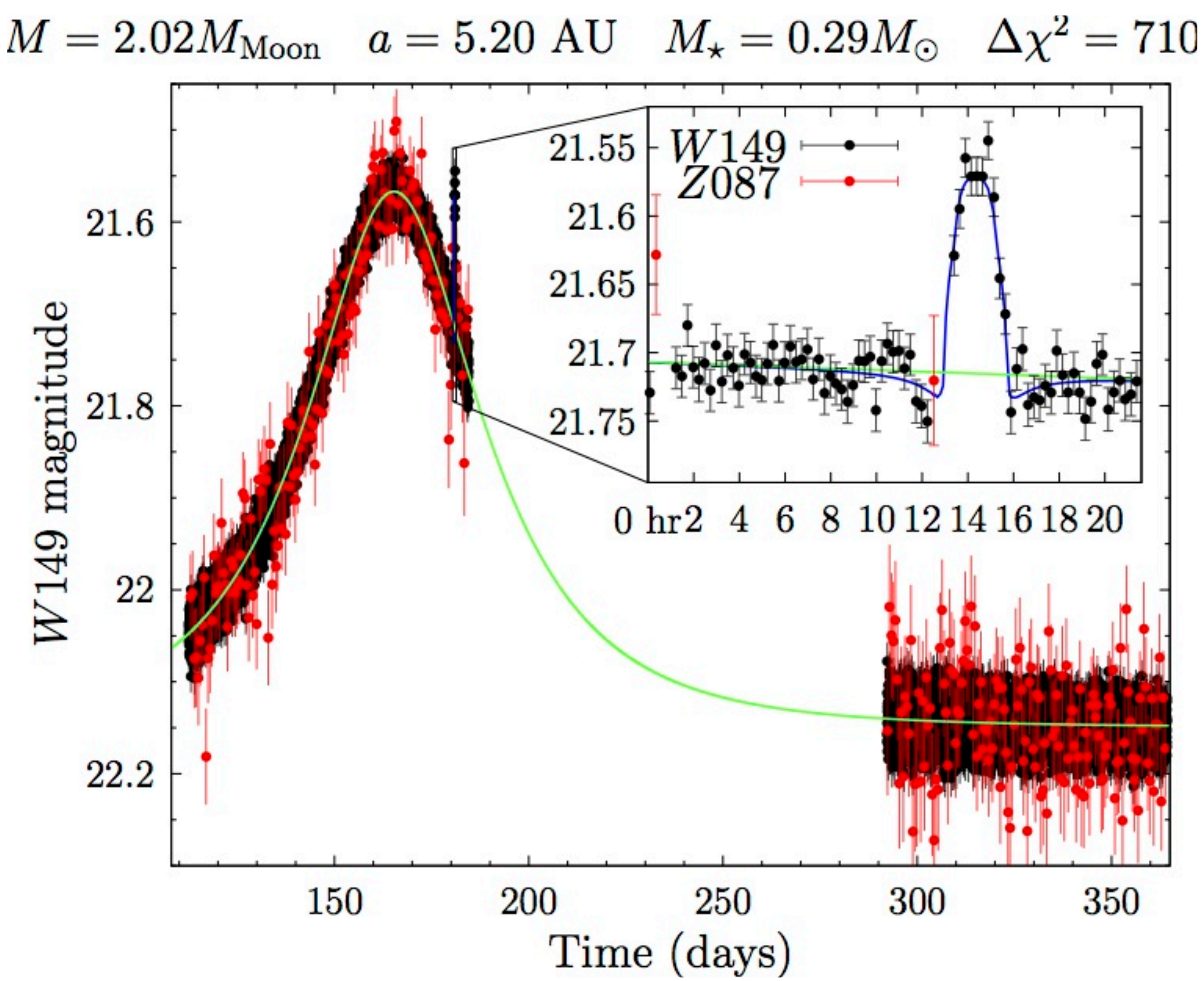


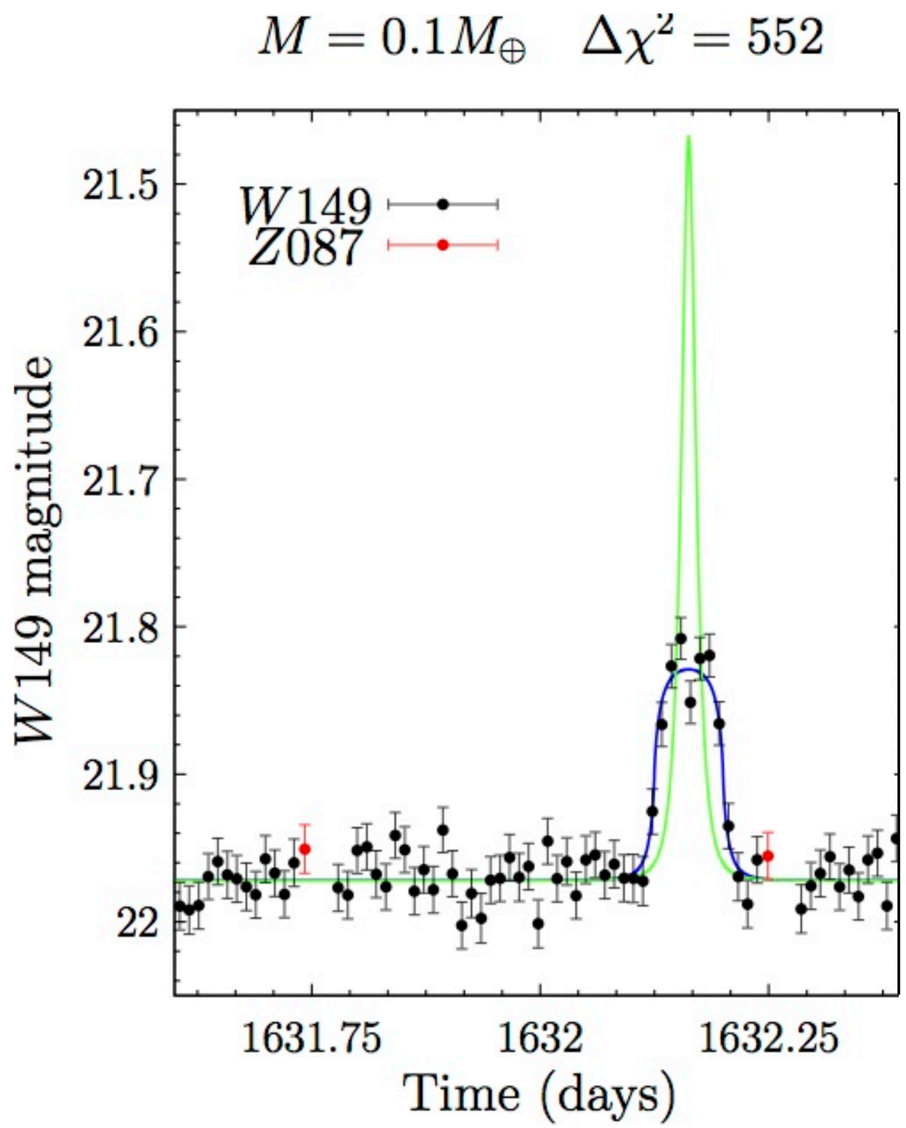
Resolve and characterize stellar populations very efficiently out to large distances (e.g., 47 Tuc + SMC/LMC - e.g., Kalirai et al. 2012)

Local Group dwarf galaxies efficiently found from LSST+Euclid/WFIRST-AFTA data sets; TMT will provide spectroscopy to confirm systems, measure velocity dispersions, metallicities, star formation histories, as well as proper motions

more dwarf galaxy discussion in B. Willman's talk

Science Case #5: microlensing follow-up





2x the mass of the Moon at ~5 AU!
(~27σ)

free-floating Mars
(~23σ)

also sensitive to exo-moons!

more exoplanet discussion in G. Laughlin's talk