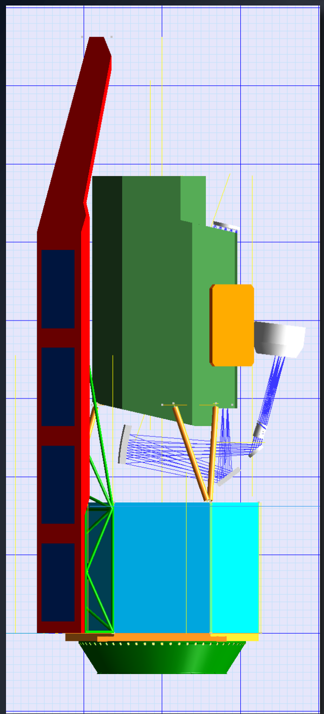
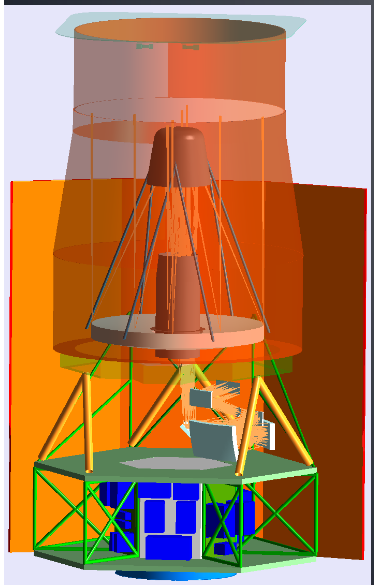
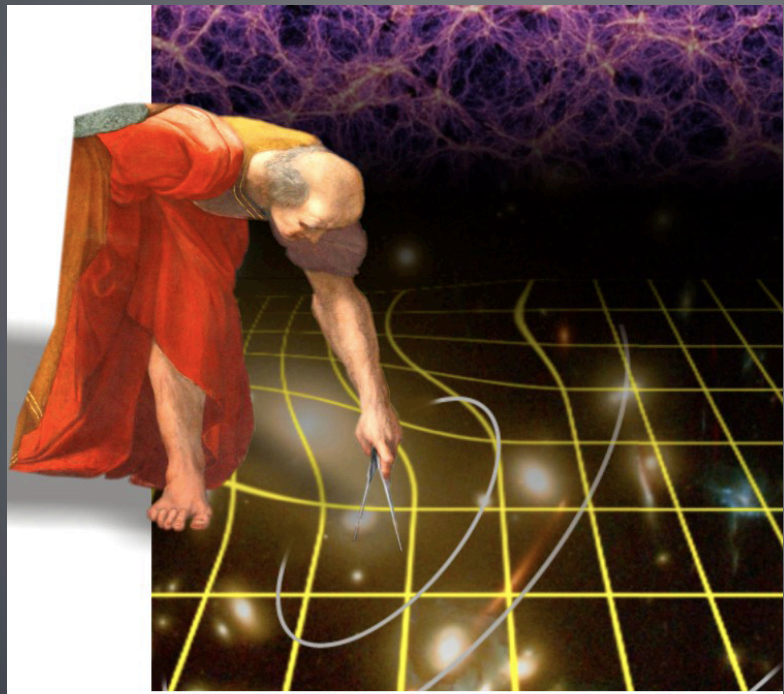
Euclid/WFIRSTの現状と日本の参画について

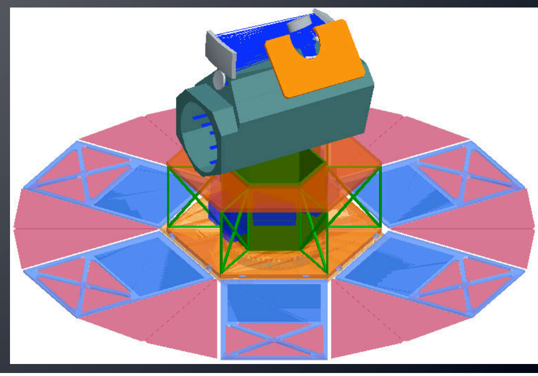






- Dark Energy
- Exoplanet Microlensing
- Near Infrared Sky Survey
- General Observer Program

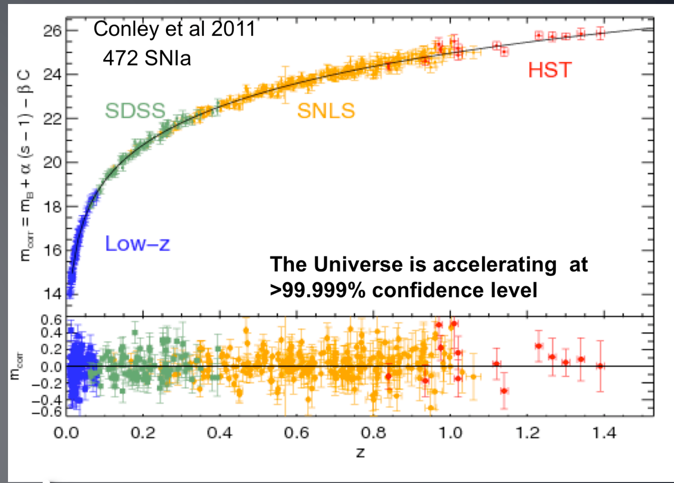
住　貴宏 (Osaka Univ)
WFIRST SDT member



Late 20th century's biggest discoveries

Accelerating expansion of universe

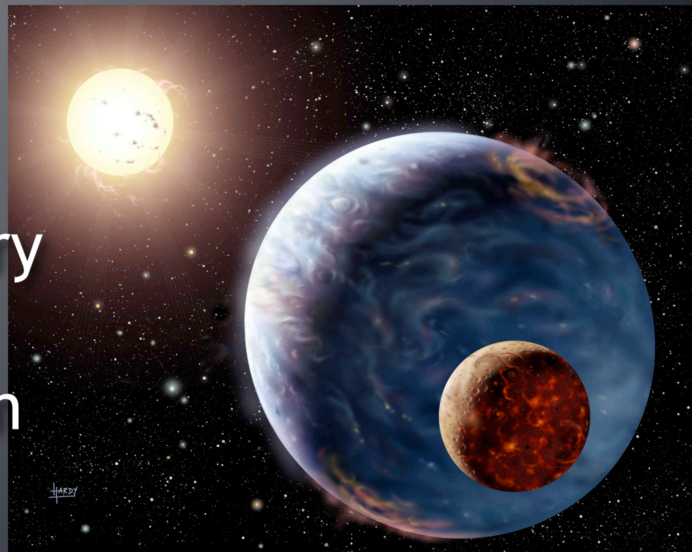
- Cosmic acceleration history via
  - Weak lensing (WL)
  - Supernovae (SN)
  - Baryon Acoustic Oscillation (BAO)
  - Red shift space distortion (RSD)
- Structure growth via WL, RSD
- Test Einstein's gravity and Modified Gravity



Exoplanets

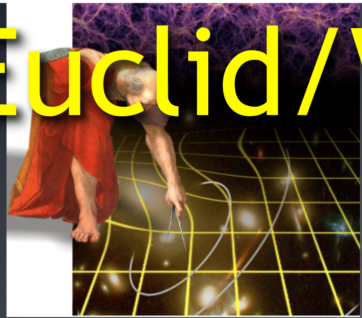
- Complete statistical census of Planetary systems which Kepler started

→ Complementary to direct observation



Euclid/WFIRST difference

Euclid



(Dark Energy mission, 2019~)

Primary: 1.2m

Life time: 6.25yr

Optical Im + IR(YJH) Im, Spec

FOV: $0.54\,deg^2$

Wide 15kdeg^2 ,M_{AB}=24.5,YJH_{AB}=24

Deep 40deg^2 ,M_{AB}=26.5,YJH_{AB}=26

- Dark Energy
  - Weak Lensing
  - Baryon Acoustic Oscillation

WFIRST

WFIRST Wide-Field Infra-Red Survey Telescope

(General observatory, 2022~)

Primary: 1.1-2.4m

Life time: 3-5 yr

IR(JHK) Im, Spec

FOV: $0.35\text{-}0.6\,deg^2$

High latitude 3400deg^2 ,$YJHK_{AB}$=26

Galactic Plane 1240deg^2 ,$YJHK_{AB}$=25.1

Supernova wide 6.5deg^2 , JHK_{AB}=28.1

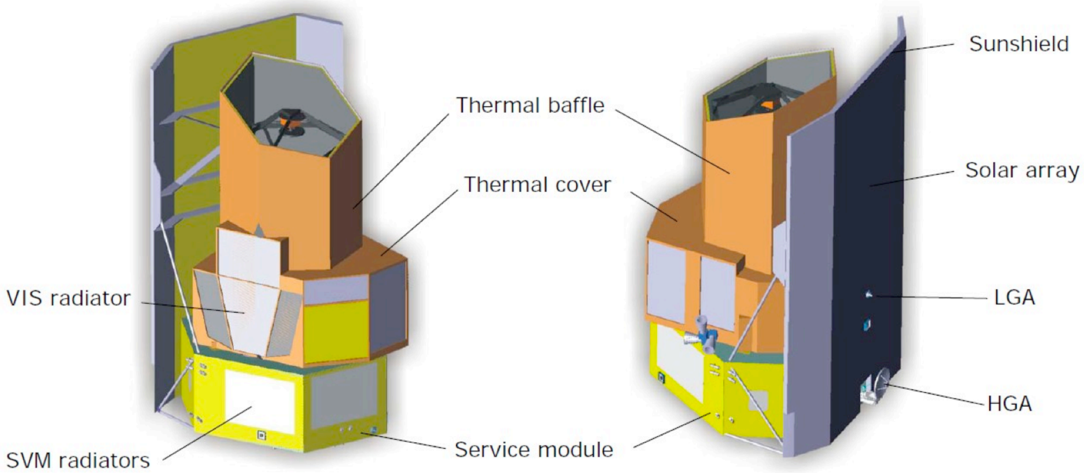
Supernova deep 1.8deg^2 , JHK_{AB}=29.6

Galactic Bulge 3.4deg^2

- Dark Energy
  - Weak Lensing
  - Baryon Acoustic Oscillation
  - Super Novae
- Exoplanet Microlensing
- Near Infrared Sky Survey
- General Observer Program (10%)

Euclid: telescope concept

Astrium concept



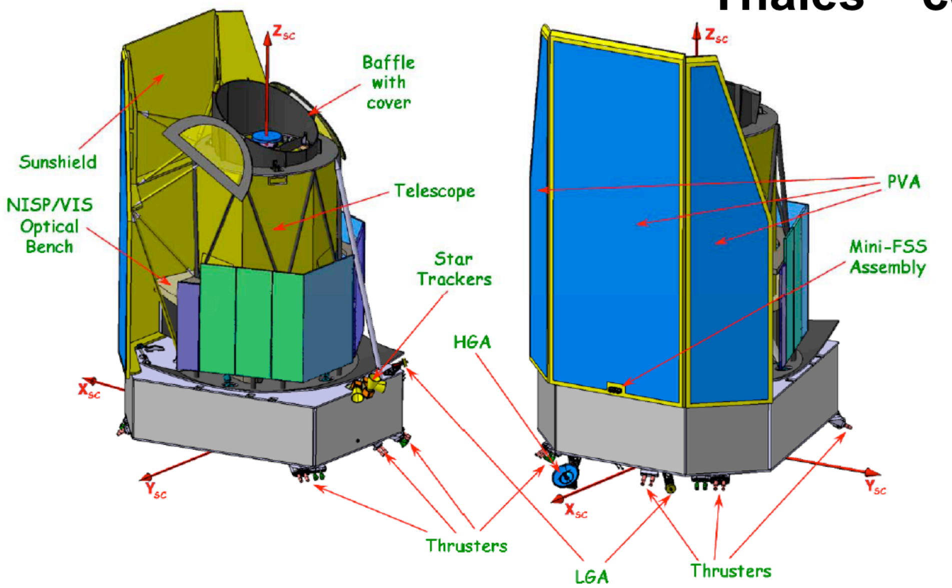
Telescope

- Primary Mirror: SiC
- Cold Telescope (T~150K)
- Passive Thermal Control

AOCS

- Fine pointing: Cold Gas + FGS & Gyro
- Slews: Cold Gas + Star Tracker & Gyro

Thales concept



Telescope

- Primary Mirror: Zerodur
- Cold Telescope (T~240K)
- Active Thermal Control

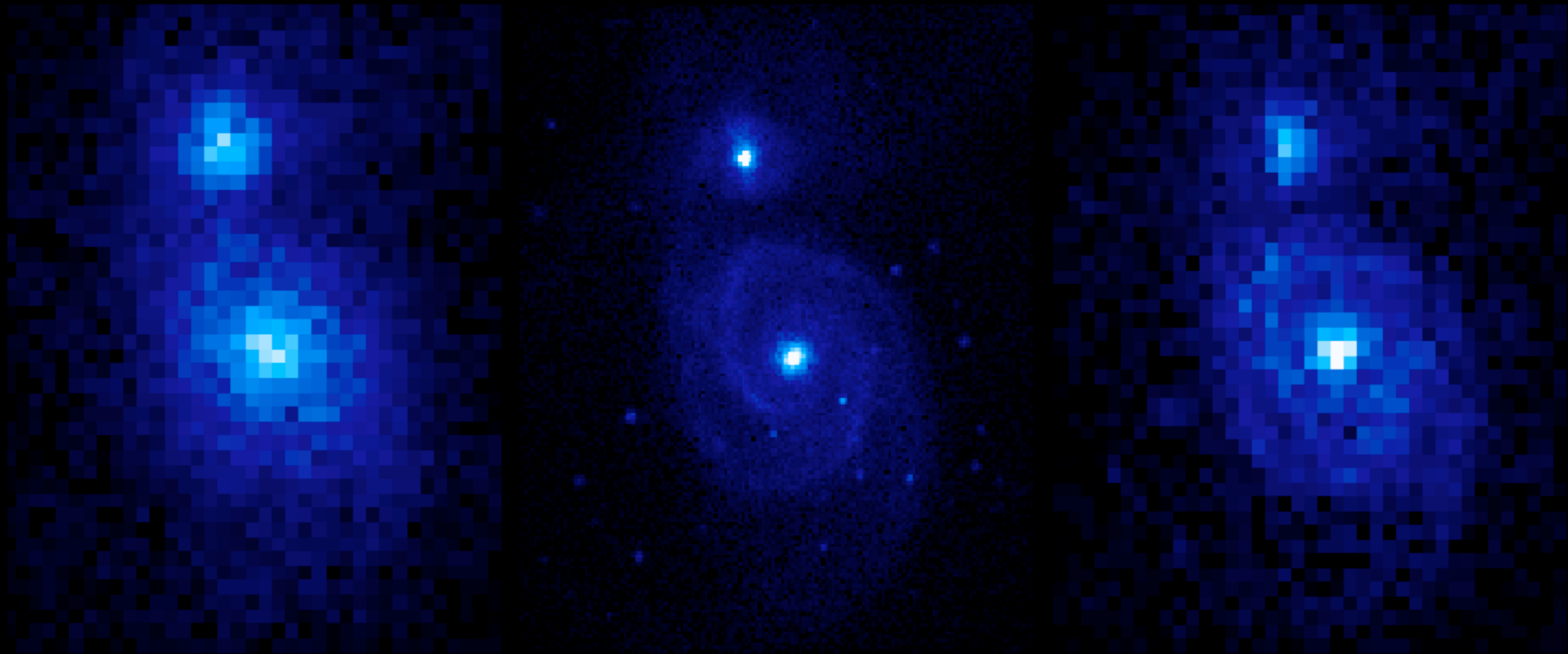
AOCS

- Fine pointing: Cold Gas + FGS & Gyro
- Slews: Reaction Wheel + Star Tracker & Gyro

Euclid : SDSS@ 1<z<3

Euclid Consortium

M51

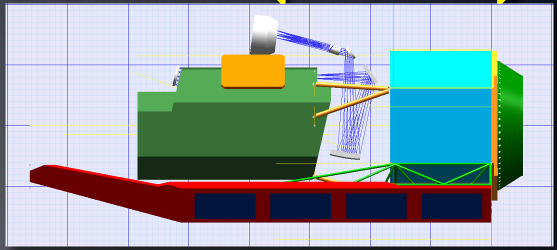


SDSS @ z=0.1 | Euclid @ z=0.1 | Euclid @ z=0.7

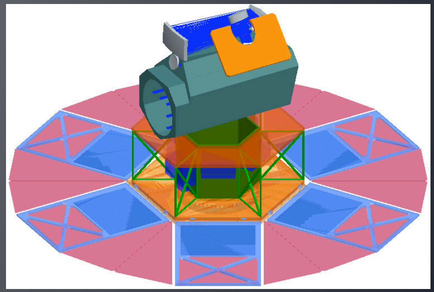
Euclid images of z~1 galaxies will have the same resolution as SDSS images at z~0.05 and be at least 3 magnitudes deeper.

WFIRST design reference mission (DRM)

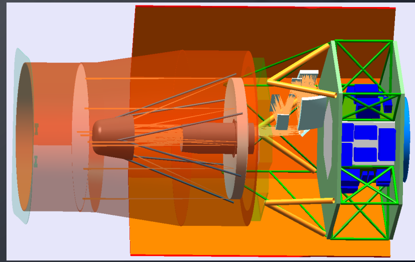
- DRM1, fulfill NWNH alone
  - 1.3m aperture, unobscured (to fit ATLAS V)
  - 5 year mission
  - 2.4um cutoff
  - 0.356 deg^2 (36 H2RG with 0.18"/pixel)
  - 0.671 deg^2 (18 H4RG with 0.17"/pixel) DRM1a
  - Prisms: 1.7-2.4um (galaxy redshift survey) and 0.6-2.4um (SN)



- DRM2 fulfill NWNH with Euclid, LLST(NASA contribute to Euclid)
  - 1.1m aperture, unobscured (to fit Falcon9)
  - 3 year mission
  - 2.4um cutoff
  - 0.585 deg^2 FOV (7x2 H4RG(-10) at 0.18"/pixel)
  - Prisms 1.7-2.4um (galaxy redshift survey) and 0.6-2.4um (SN)



- NRO-1 (gifted by National Reconnaissance Office)
  - 2.4m aperture
  - 0.35 deg^2 FOV (16 H4RG(-10) at 0.13"/pixel)

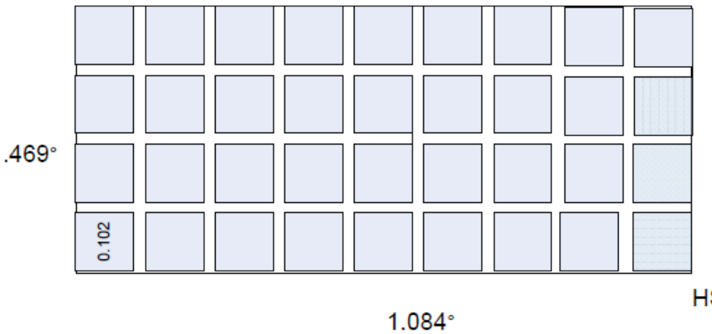


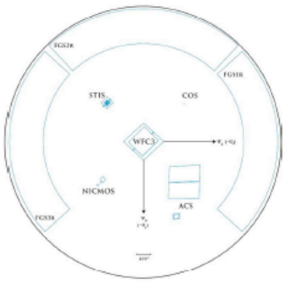
DRM1 layout

Channel field layout for WFIRST “H2E1”

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)

ImC: 9x4 @ 0.18"/p;





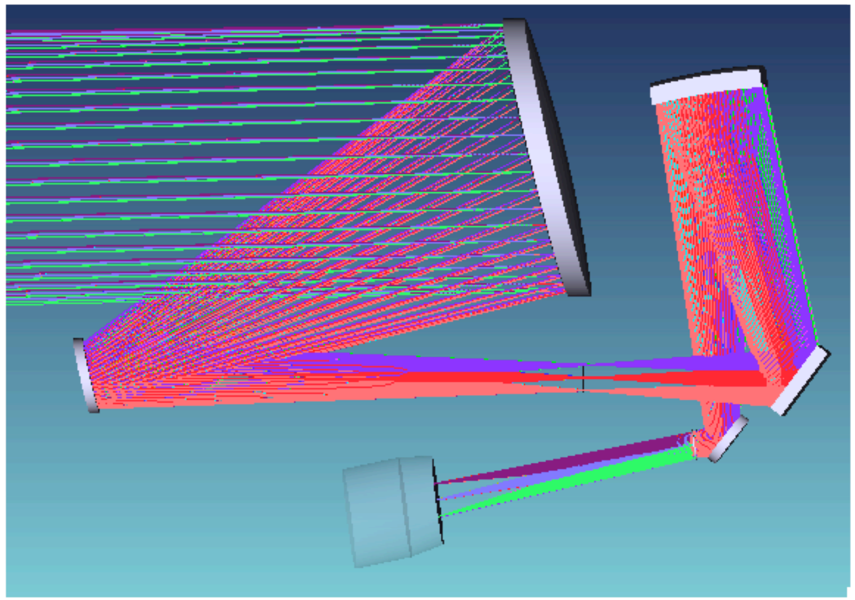
HST [all instruments]

JWST [all instruments]

Each square shown is physically a 2040 x 2040 x 18um HgCdTe array [H2RG-18]

Moon (average size seen from Earth)

Unobscured optics provide clean PSF



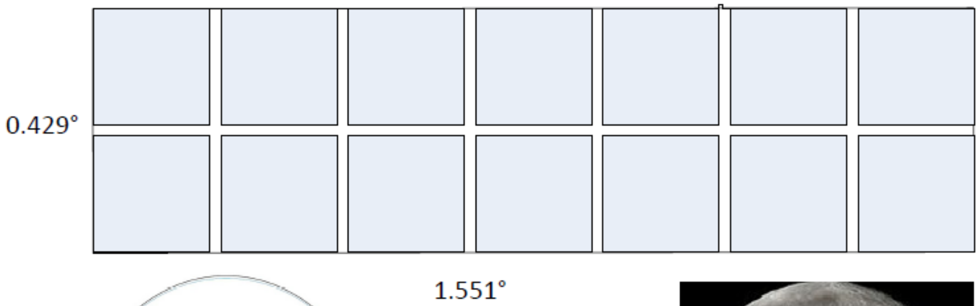
Optical ray trace layout for H2E1

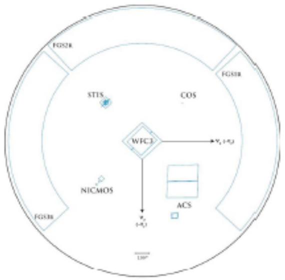
DRM2 Field of view

Channel field layout for WFIRST "DRM2"

The Field of view of the single channel which can be used in imaging (Im), BAO spectroscopy (Sp), or SN spectroscopy (SNSp) mode is shown to scale with the Moon, HST, and JWST. Each square is a 16Mpix vis-NIR sensor chip assembly (SCA), 10 um pixels

7x2 @ 0.18"/p, 0.585 sq.deg

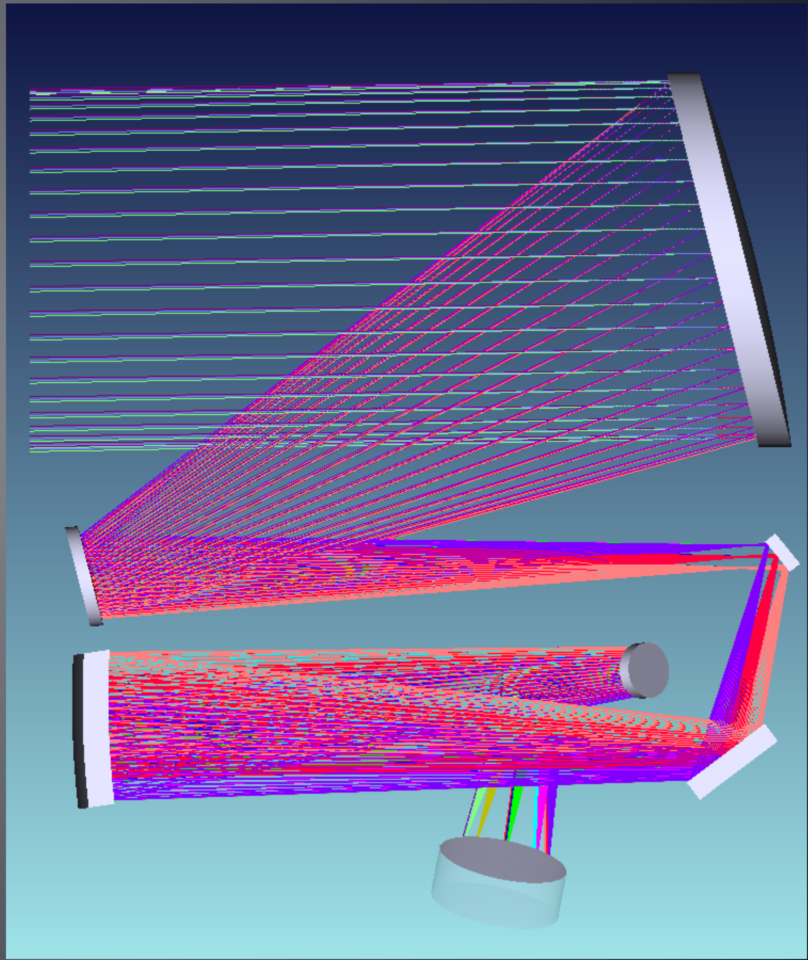




HST [all instruments]

JWST [all instruments]

Moon (average size seen from Earth)



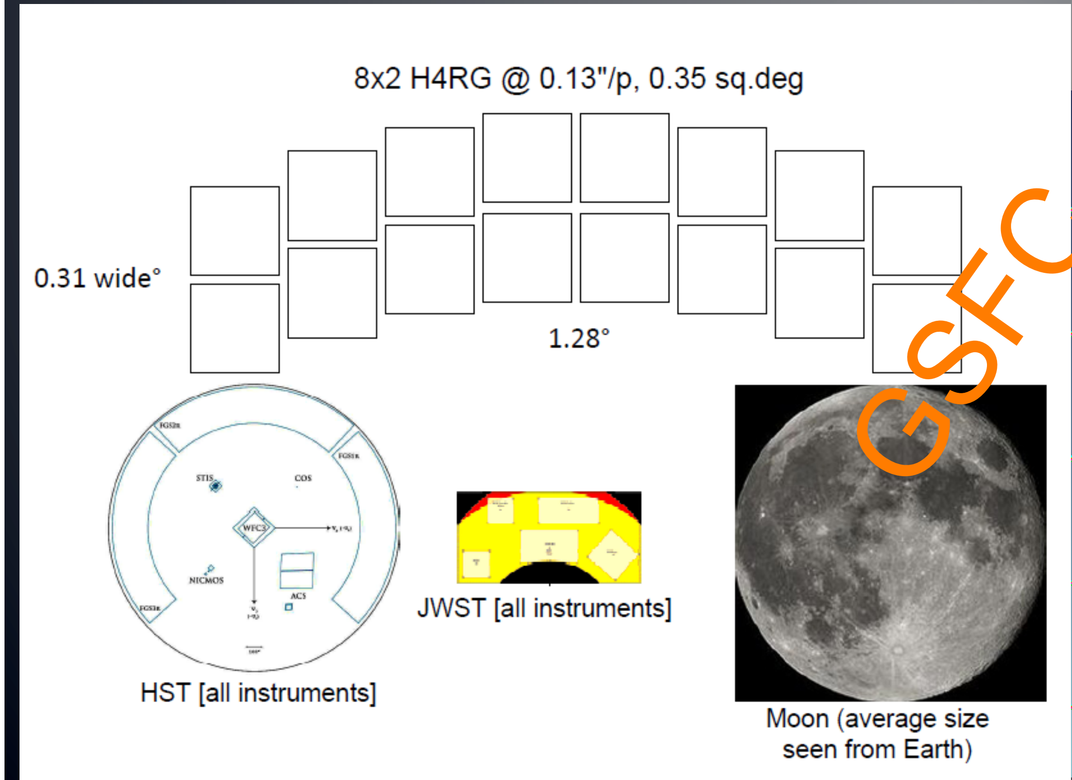
NRO-1 2.4m design

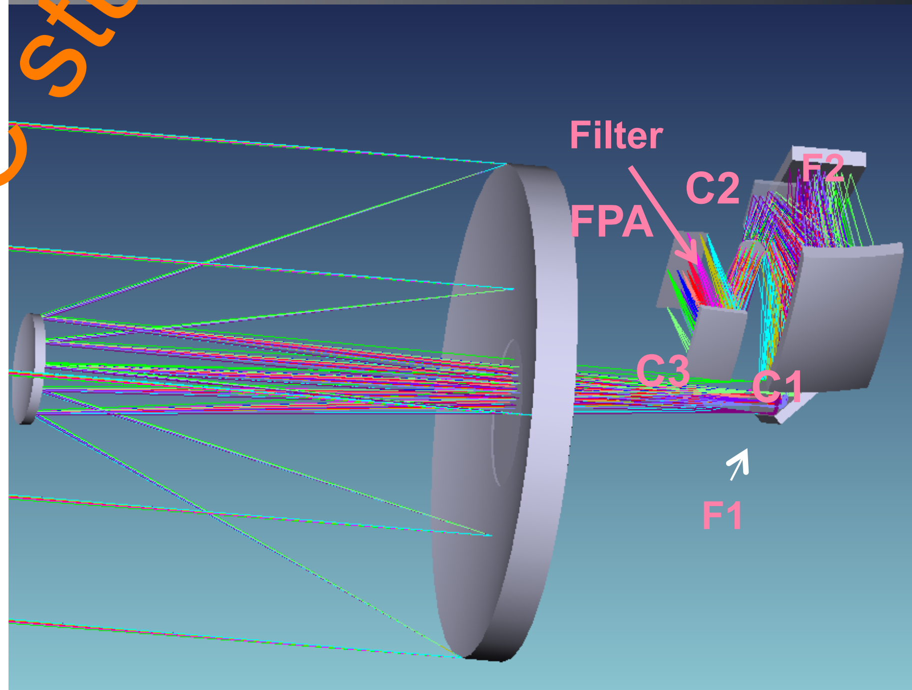
Preliminary Instrument Design:

- Based on existing telescope primary and secondary mirrors without changes
- Initial wide-field instrument shown; 2nd wide-field instrument would be a mirror image
  - 3 mirror camera, folded, with filter at pupil
- Filter & prism wheels (not shown) in ea. wide field instrument
- Fits within instrument volume implied by existing struts

Potential Payload Overview:
- 2 wide field instruments
2 small, finer sampled instruments

GSFC study

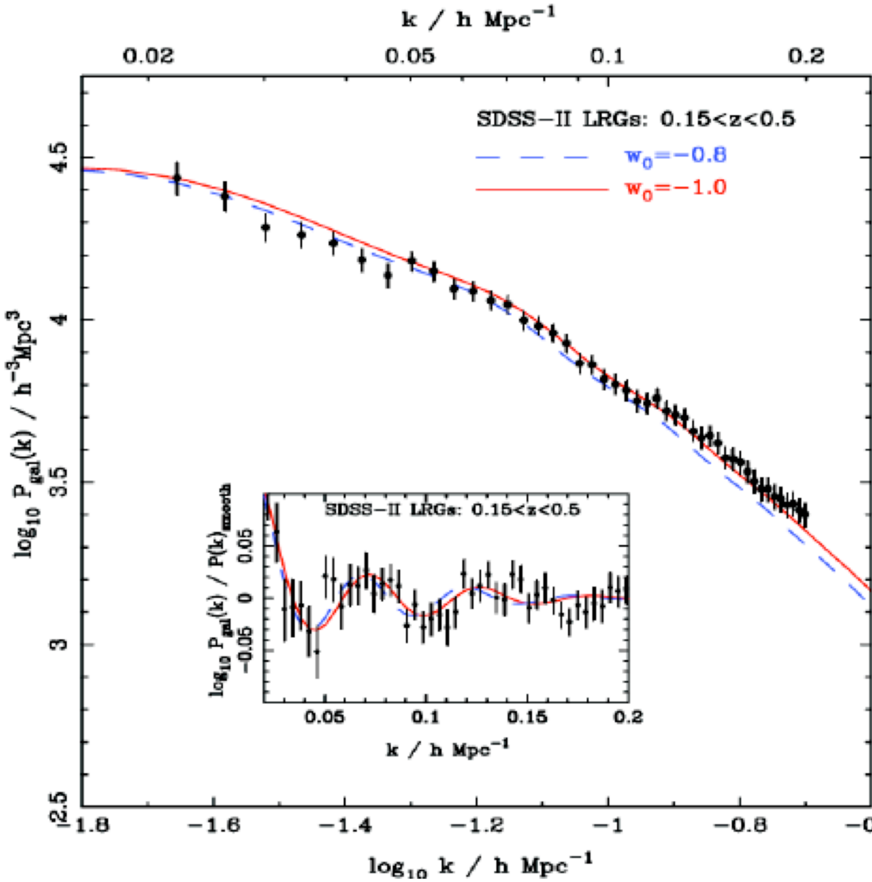




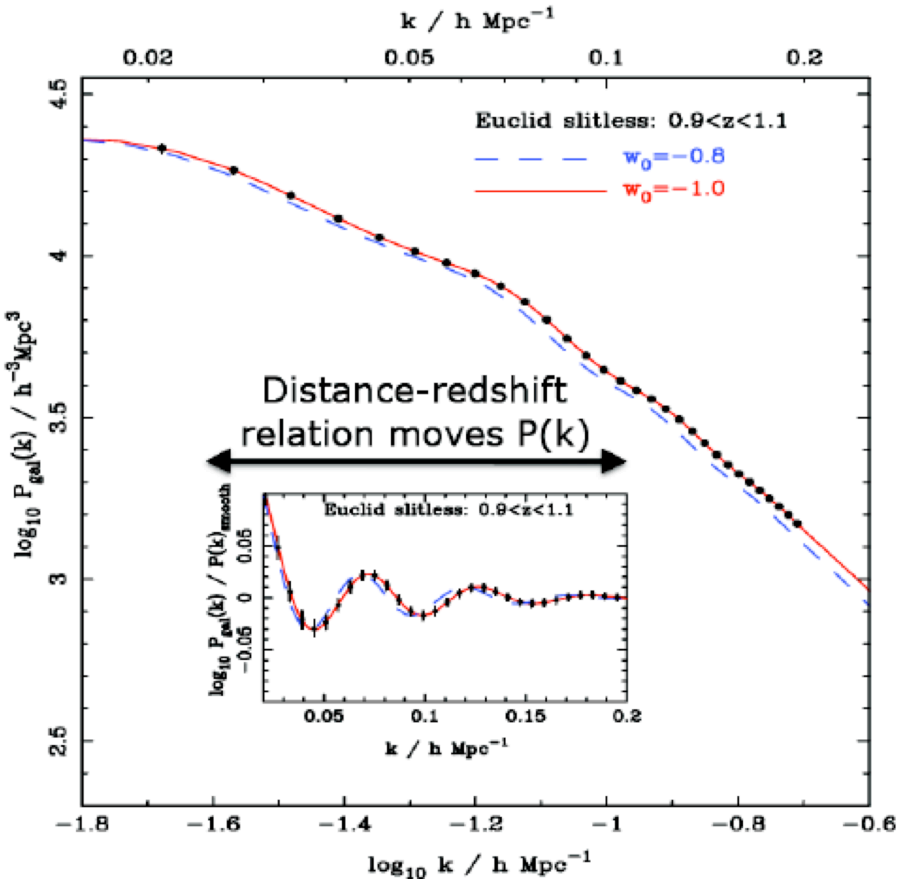
Euclid GC predicted performances

Euclid Consortium

Reconstructed galaxy power spectrum



Percival et al. 2009; arXiv:0907.1660



SDSS-II LRG galaxies - Euclid

- $V_{eff} \approx 19\ h^{-3}\ Gpc^3 \approx$ 75x larger than SDSS
- Redshifts $0<z<2$

Percentage difference [expected – measured] power spectrum: recovered to 1% .

Euclid Deep+Wide surveys feasible in 5.8 years

Euclid Consortium

Reference survey for sizing spacecraft: final survey not yet set.

Wide 15kdeg^2 ,M_{AB}=24.5,YJH_{AB}=24

Deep 40deg^2 ,M_{AB}=26.5,YJH_{AB}=26

Sky survey strategy includes:

- Instrument calibration with specific targets
- Wide and Deep fields

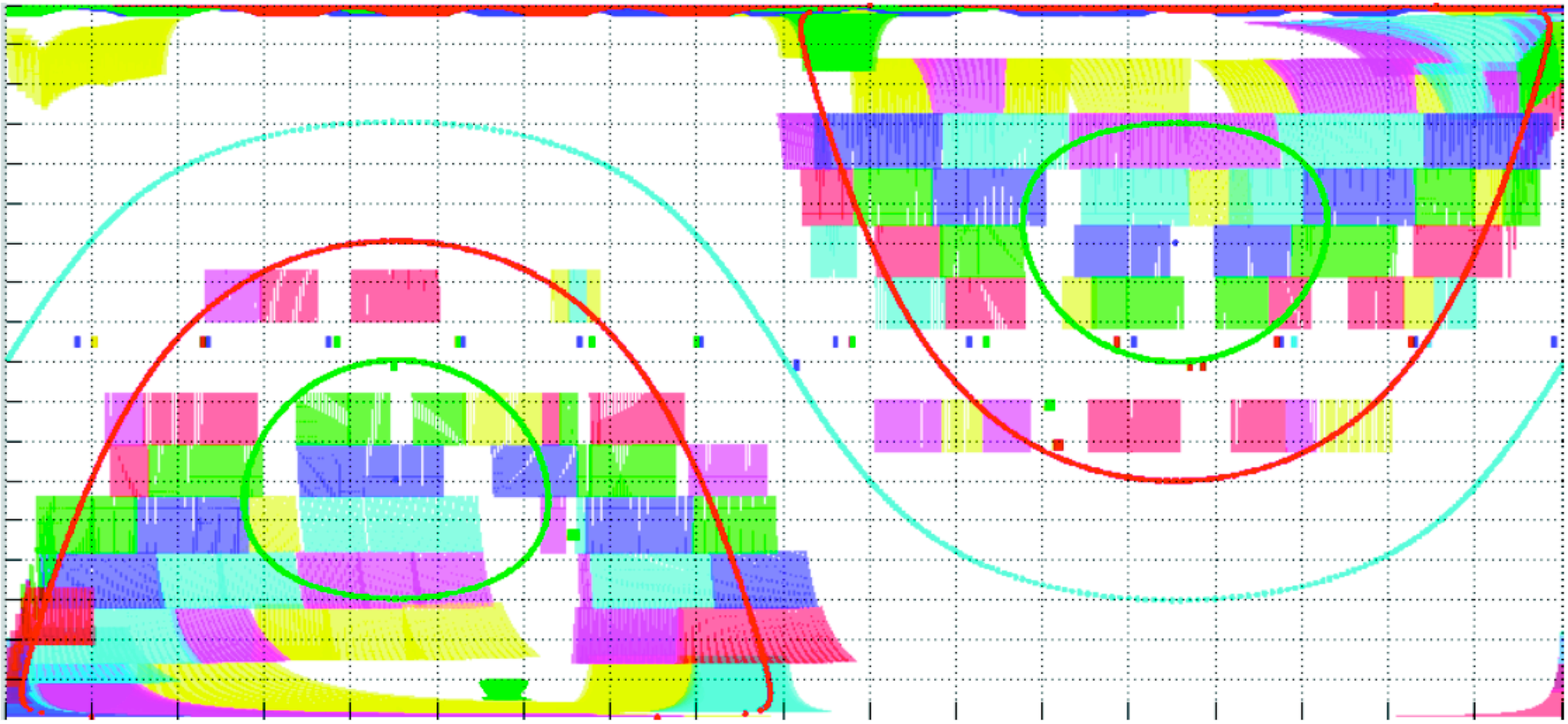
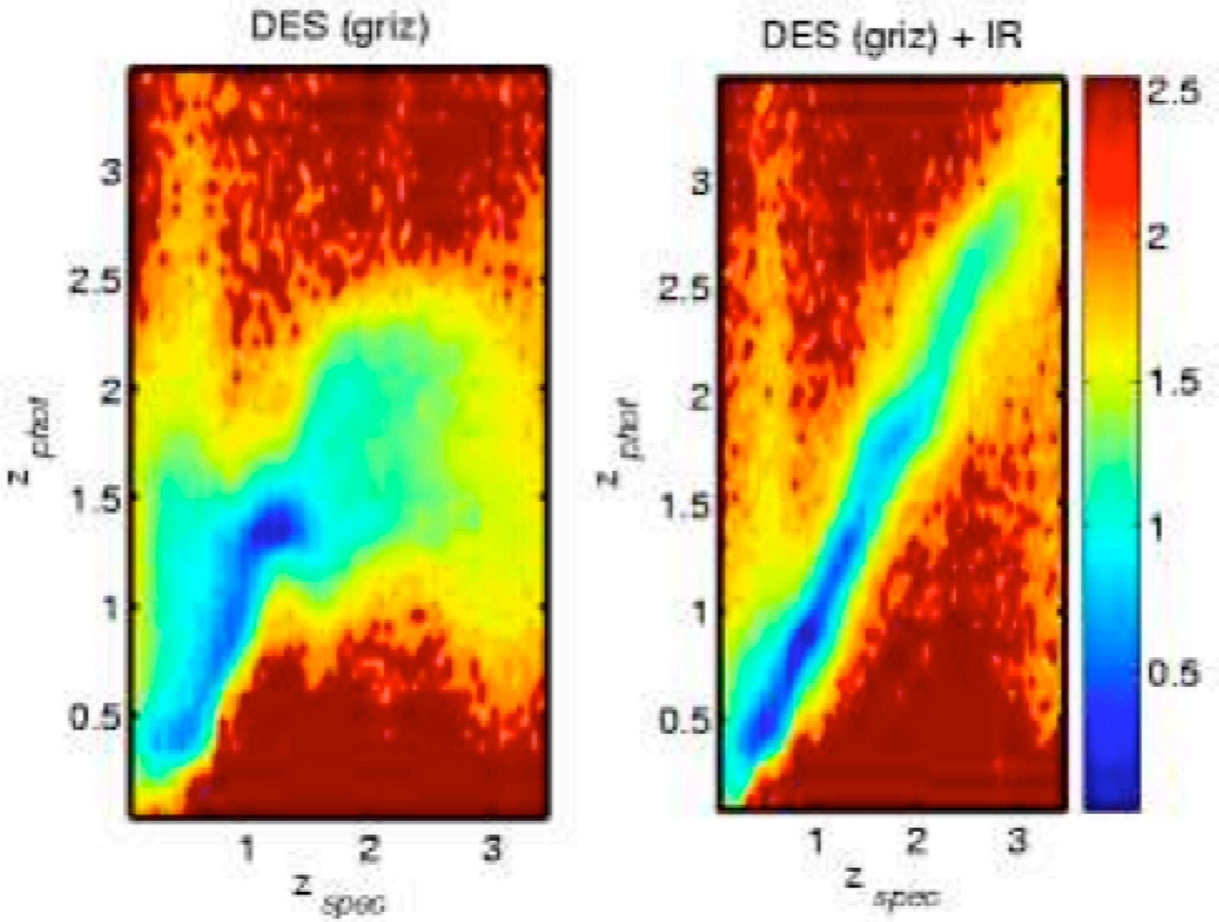


Photo-z: DES + Euclid data

Euclid Consortium

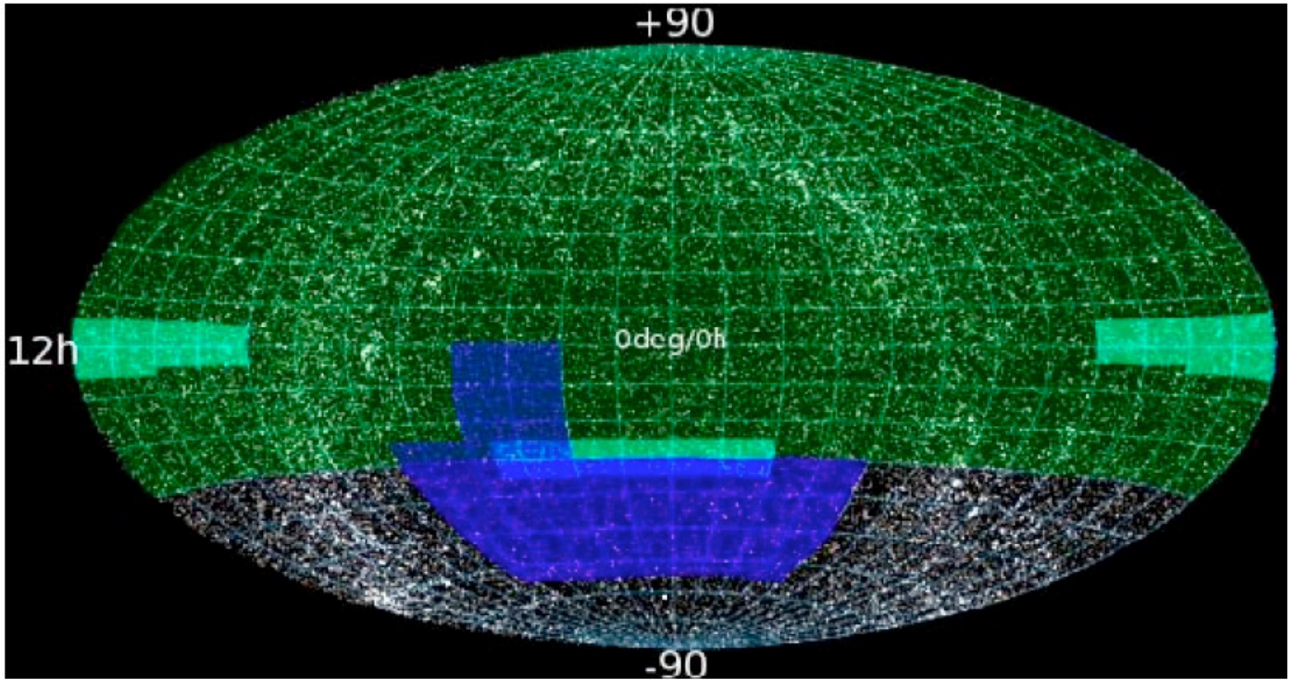


- Optical data are full part of the Euclid mission
- Requirement 0.05x(1+z)
  → 4 optical band + Euclid Y, J H sufficient
  → Need to get optical data from ground-based telescopes

Euclid : Ground surveys for visible data

Euclid Consortium

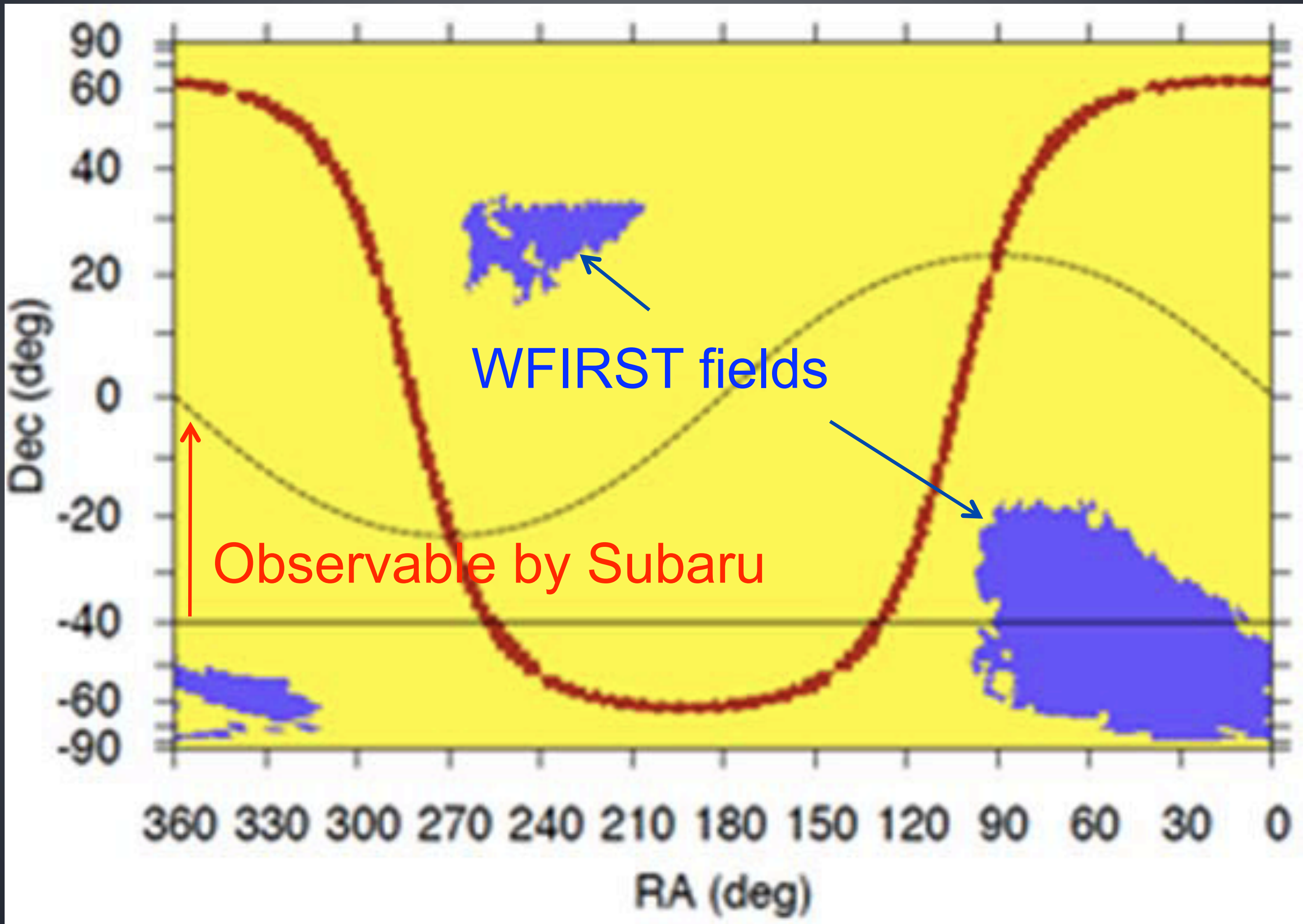
- Southern sky almost secured:
  - DES,
  - e-KIDS,
  - LSST?
- Northern sky not yet secured: several options explored:
  - PS2,
  - WHT,
  - HSC



External survey timelines	2011	2012	2013	2014	2015	2016	2017	2018
KiDS-VIKING	Survey underway		VIKING completed	KiDS completed, VIKING final release	, KiDS final release			
Pan-STARRS1	Survey underway		Survey completed		PS1 final release			
Pan-STARRS2				Survey start				
DES		Survey start		1st data release		Survey end	Final data release	
LSST								2020?
HSC?								

Survey	Area (sq deg)	U	G	r	i	z	Y	J	H	K
KiDS+VIKING	1500 Eq+SGC	24,8	25,4	25,2	24,2	23,1	22,3	22.0	21,5	21,2
Pan-STARRS1	15000 NGC+½ SGC		23,4	23.0	22,7	22,0	20,9			
PS2	15000 NGC+½ SGC		24,8	24,4	24,1	23,4	22,3			
DES	5000 ½ SGC		25,4	24,9	24,8	24,7	22,3			

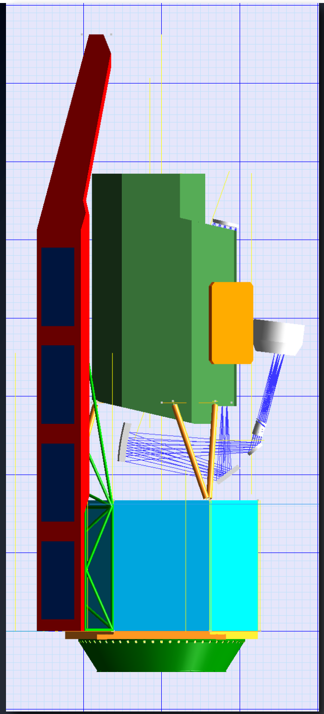
WFIRST fields

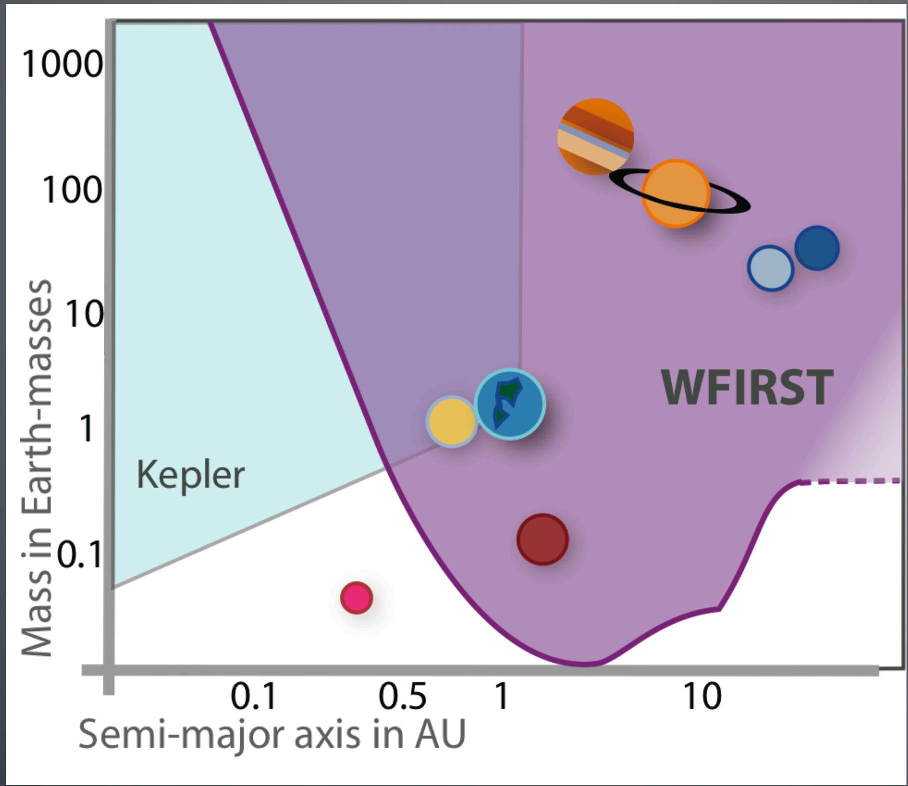


Space Microlensing Exoplanet Survey with

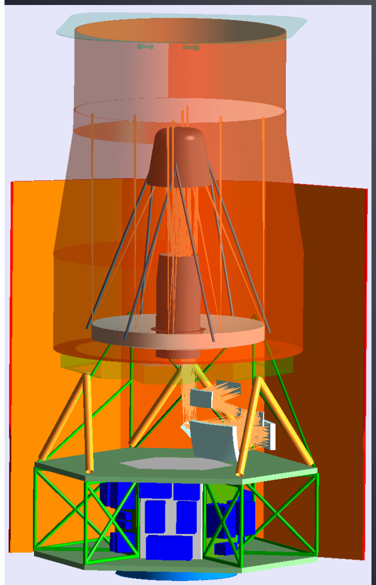
WFIRST

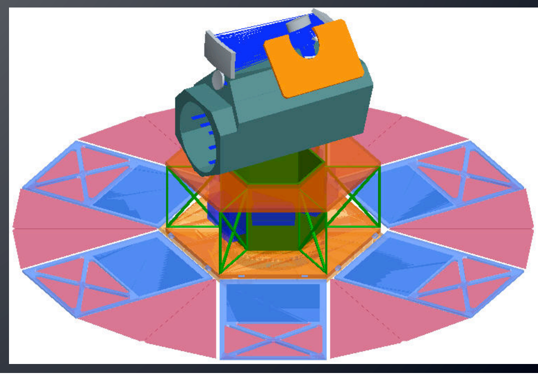
Wide-Field Infra-Red Survey Telescope



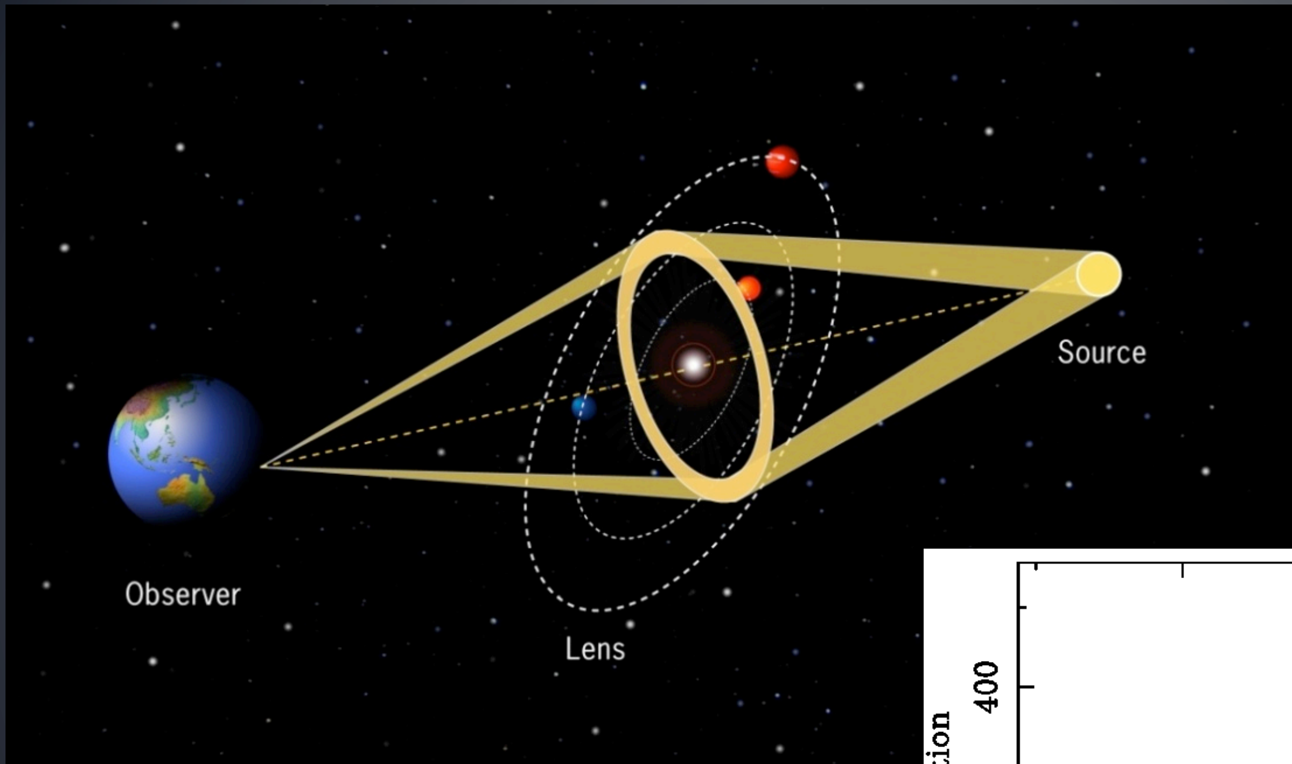


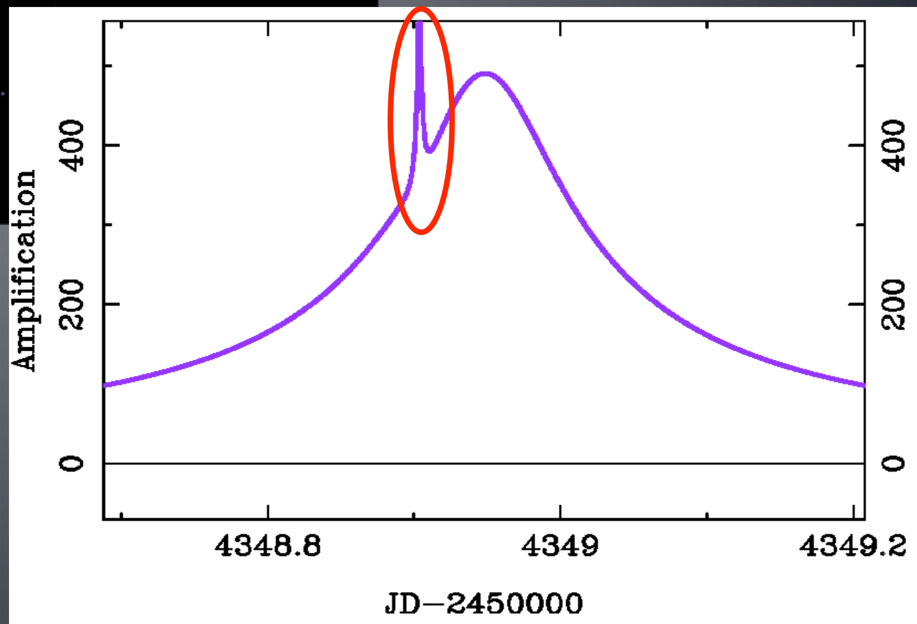
- Dark Energy
- Exoplanet Microlensing
- Near Infrared Sky Survey
- Guest Investigator Program





planetary microlensing





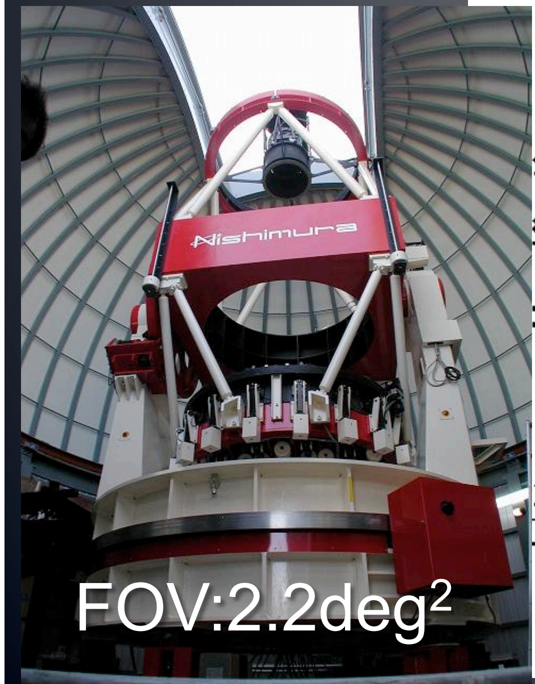
Time scale: $t_p \sim M^{1/2} \sim 1\mathrm{day}(M_J)$

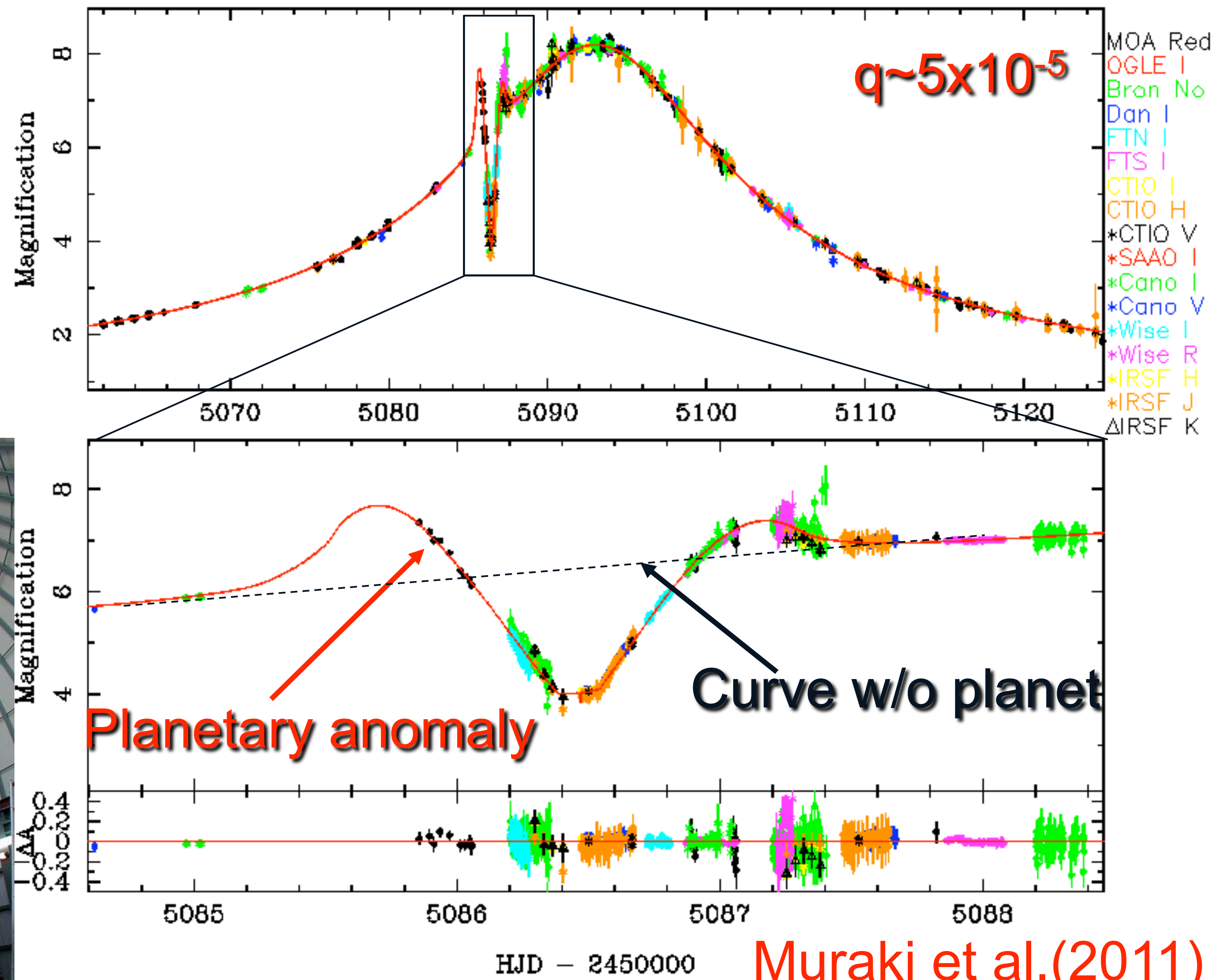
Sensitive to Cold planets outside of snowline (~3AU)

Survey & follow-up from Ground

Planetary anomaly
Is found by MOA
Survey Telescope
& followedup by
many Telescopes
Around the World

MOA-II 1.8m



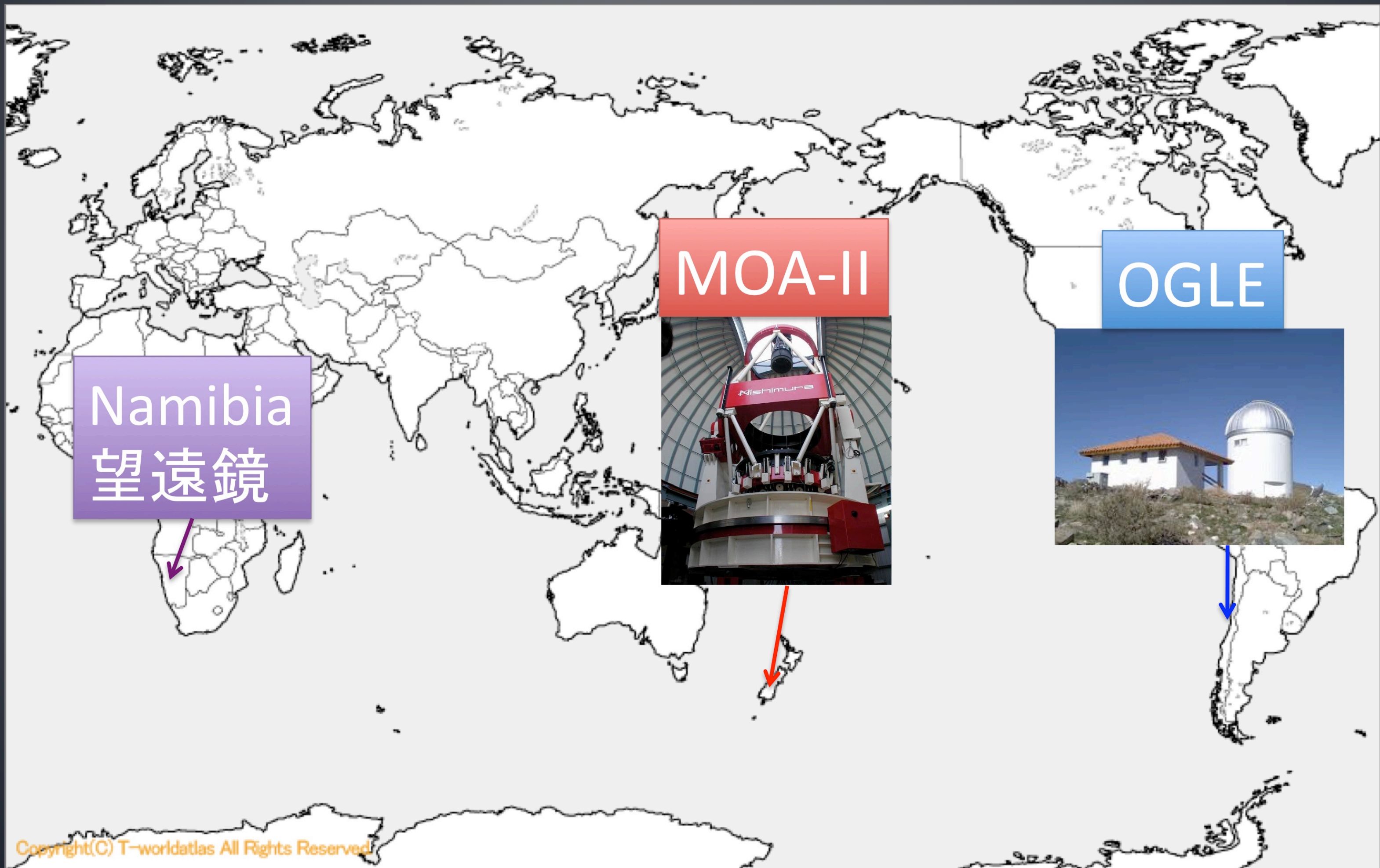


Muraki et al.(2011)

Next generation 24h survey network

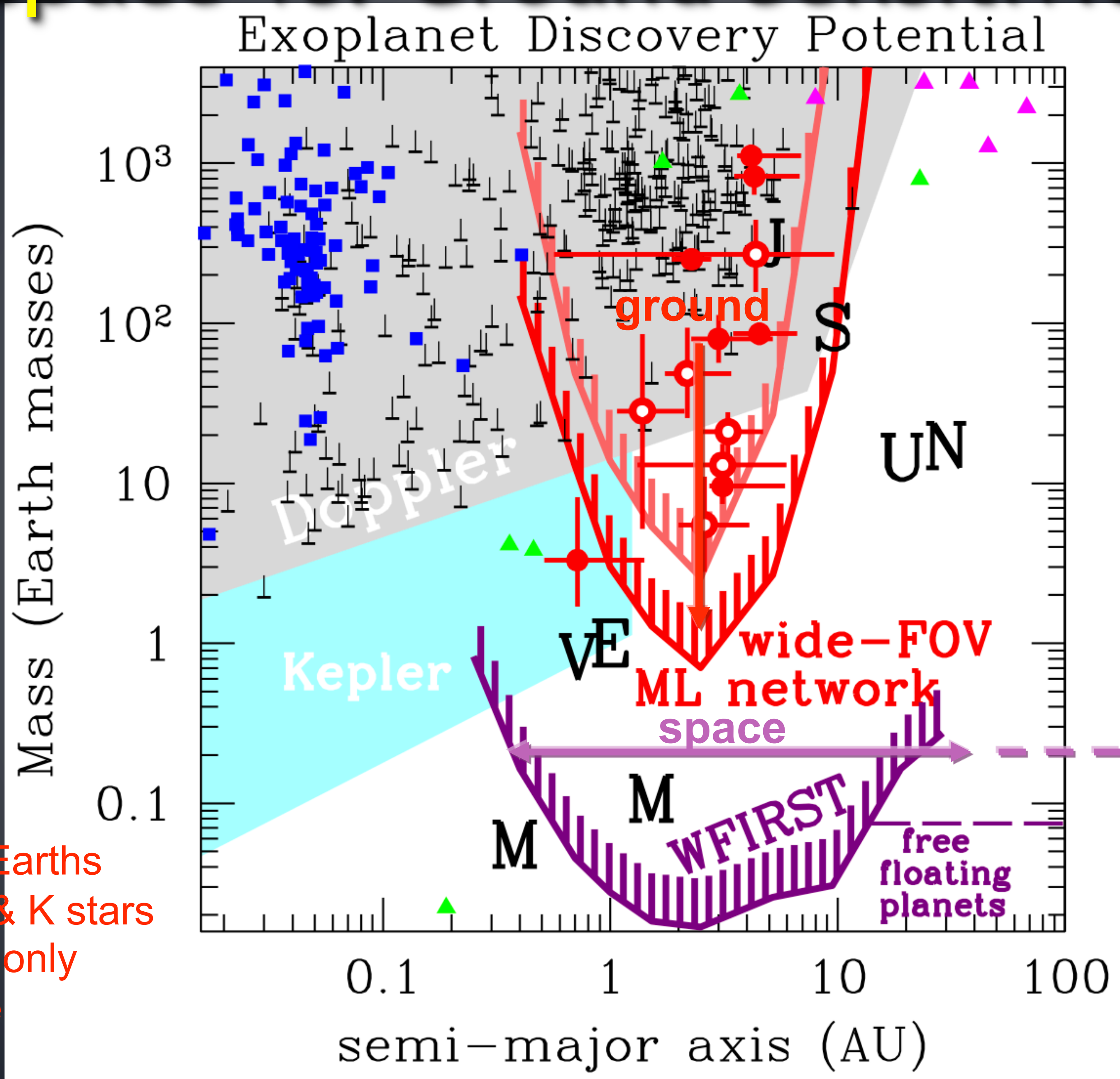
新MOA-III 望遠鏡
口径：　1.5m
FOV: 4.8平方度

ナミビア（H.E.S.S. site）
標高1800m
4-10月の晴天率：86%



24時間連続観測によって、追観測なしで惑星検出を約17個/年に大幅に上げる

Space vs. Ground Sensitivity



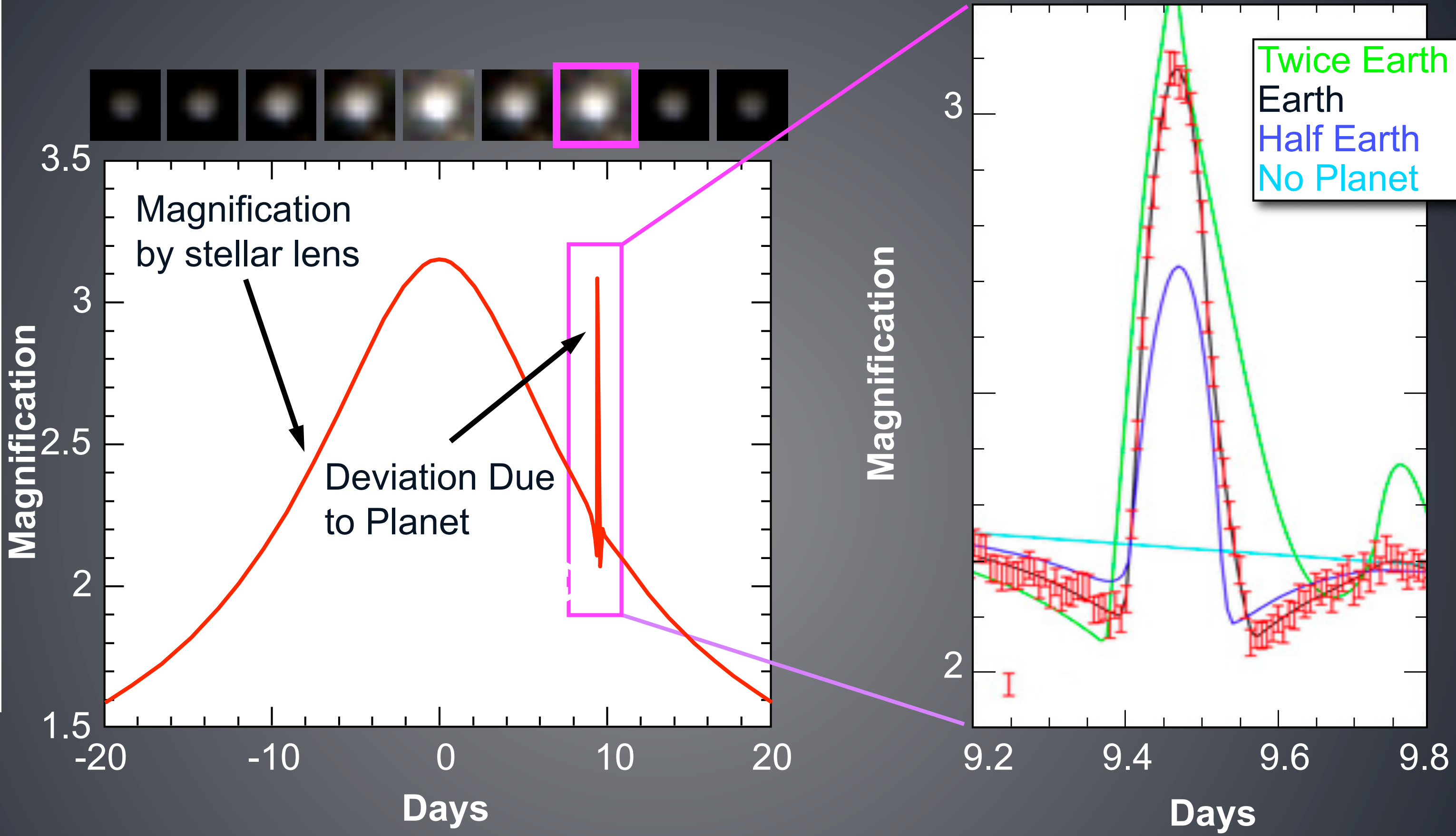
- •RV
- •transit
- •Direct image
- •Microlensing

Expect ~190 free-floating Earths

Habitable Earths orbiting G & K stars accessible only from space

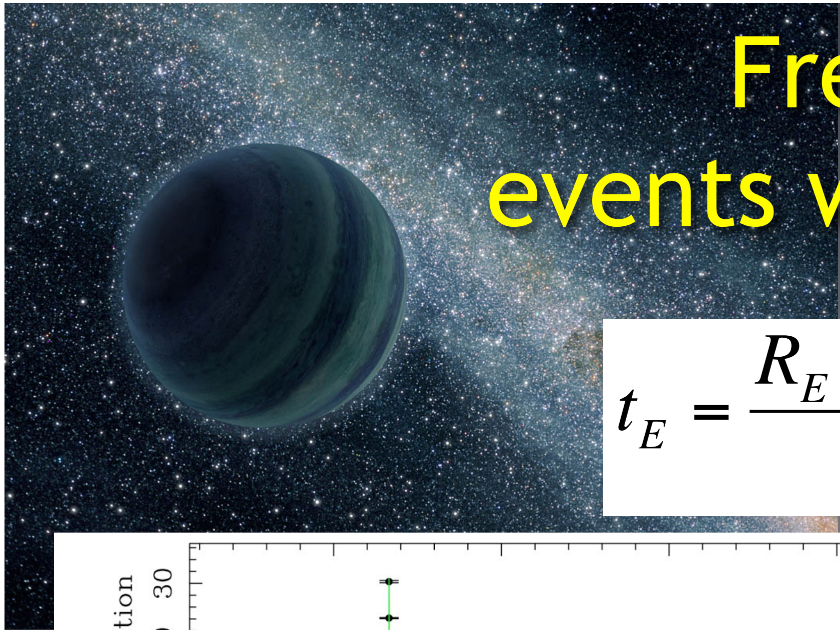
Extraction of Exoplanet Signal

Time-series photometry is combined to uncover light curves of background source stars being lensed by foreground stars in the disk and bulge.



- •300Mstars
- •15min cadence
- •72 day continuous observation x7

Detailed fitting to the photometry yields the parameters of the detected planets.



Free-Floating Planet, events with timescale $t_E < 2$ days

$$t_E = \frac{R_E(M,D)}{v_t} \sim \sqrt{M/M_J}\ day$$

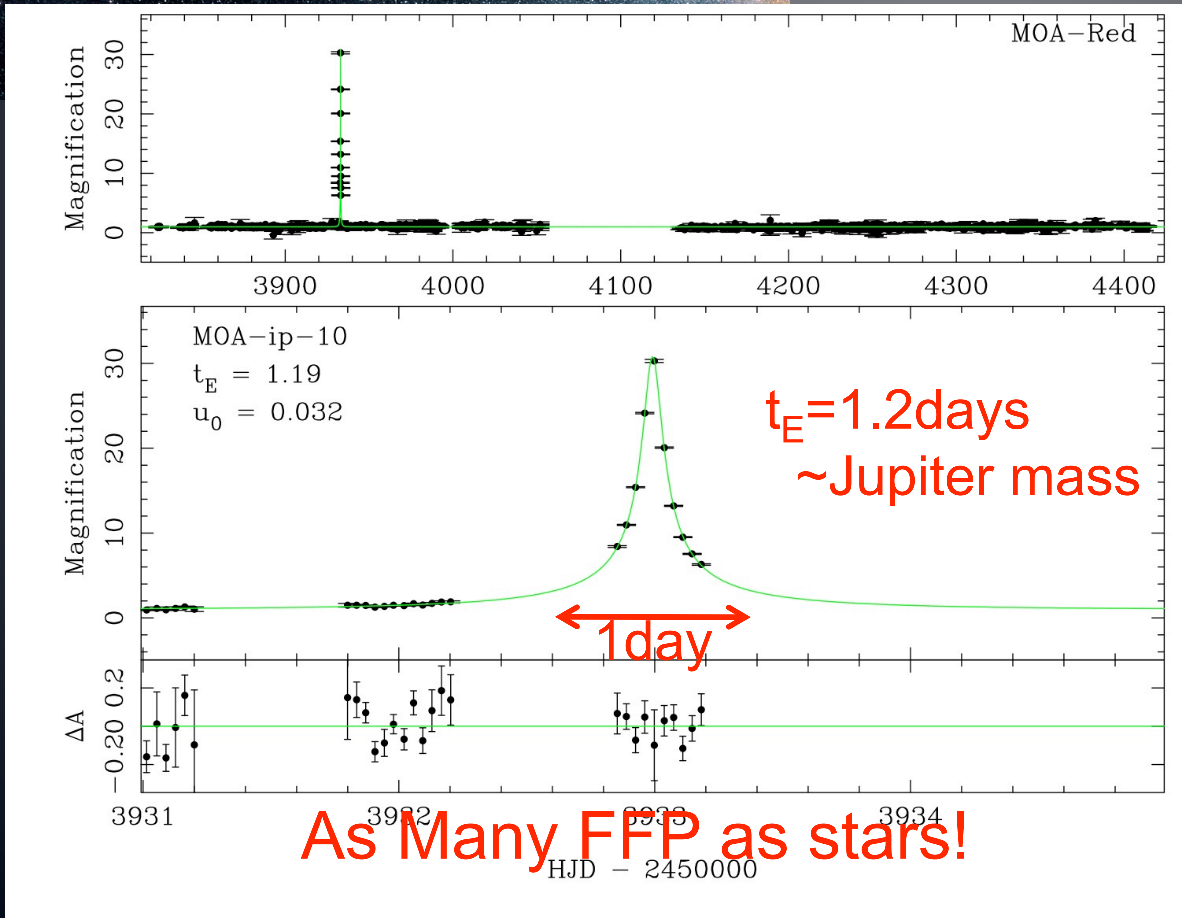
~20days for stars

M : lens mass

M_J: Jupiter mass

D : distance

v_t: velocity

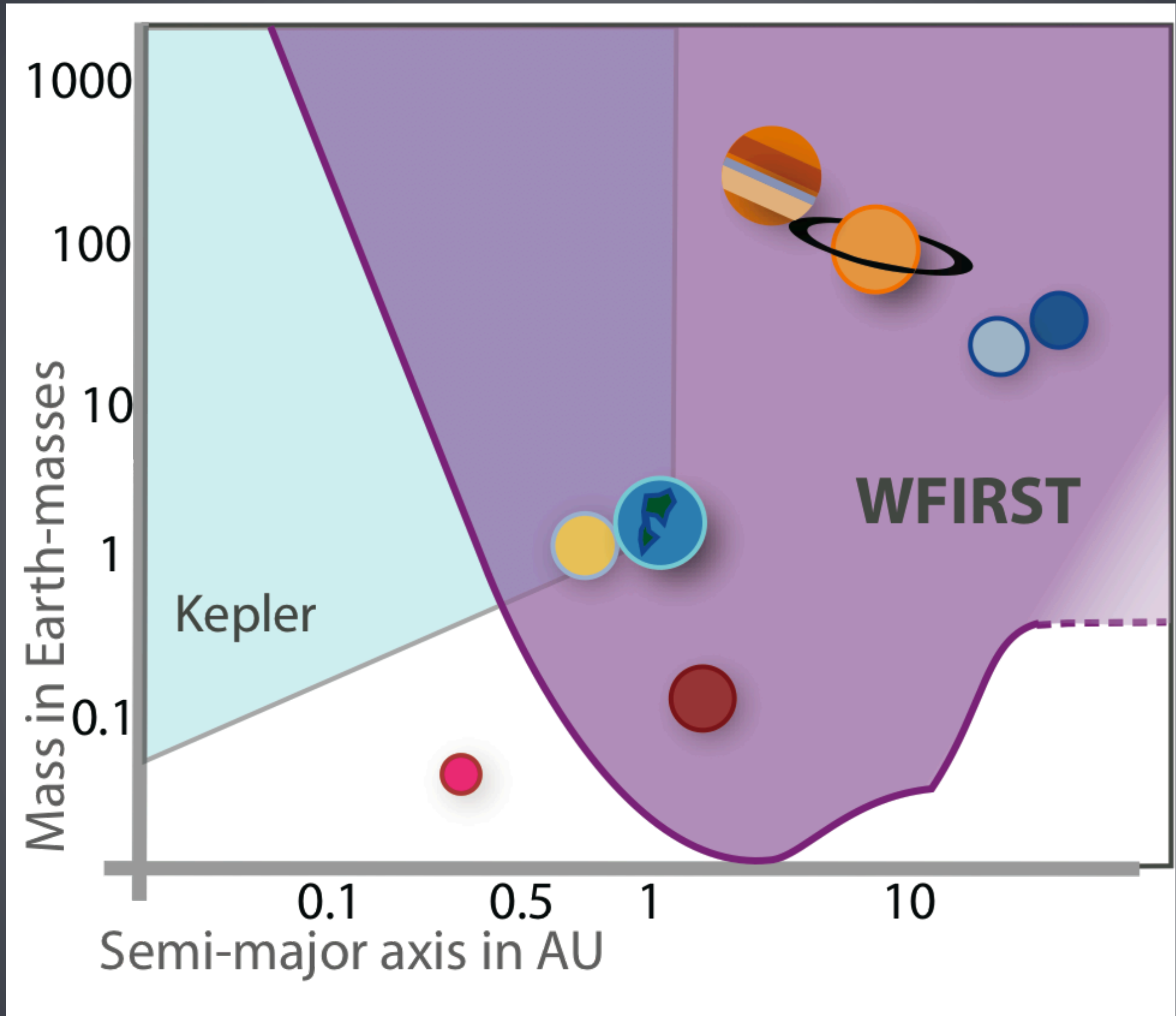


WFIRST can detect

- 2000 free-floating planet
- 100 ($< M_\oplus$)

TS et al. 2011

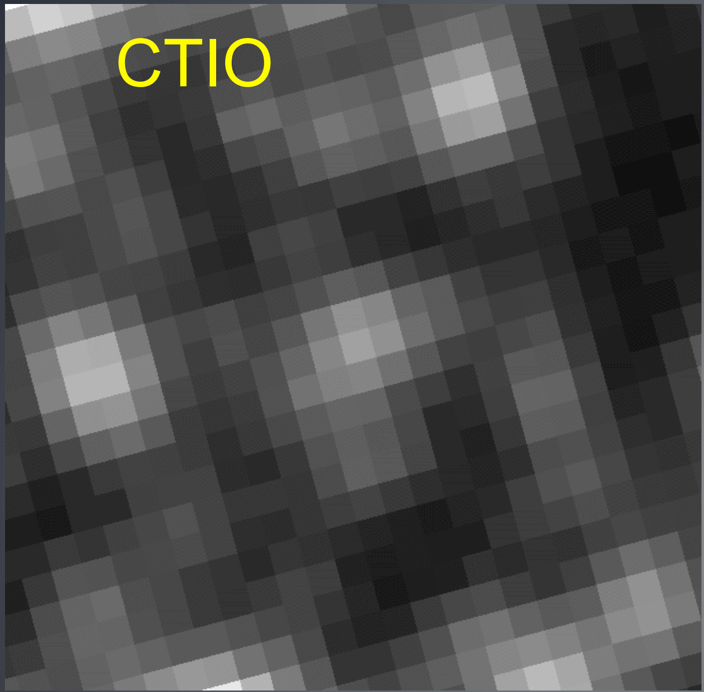
Kepler vs. WFIRST

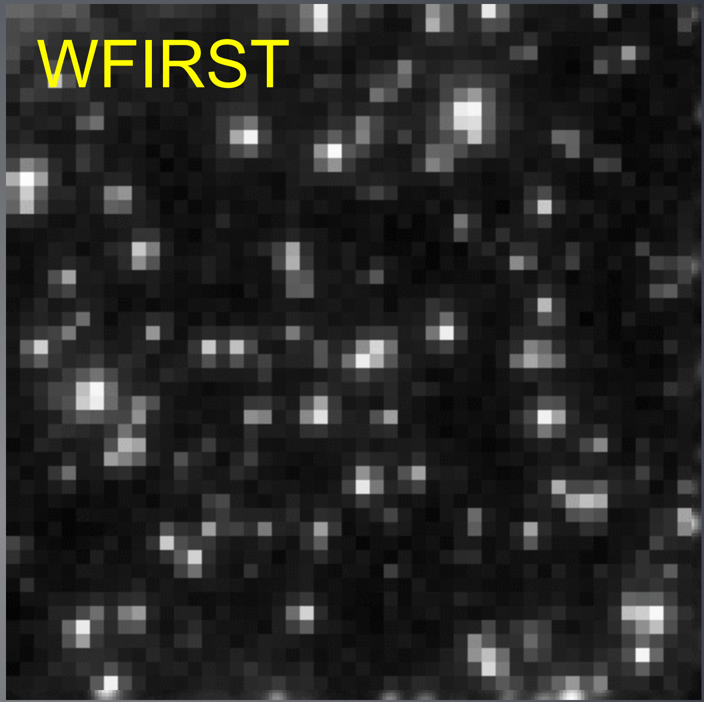


Complete the census of planetary systems in the Galaxy

- 3000 bound planet, 200 (< 1 $M_\oplus$)
- 2000 free-floating planet, 100 (< 1 $M_\oplus$)

Ground-based confusion, space-based resolution

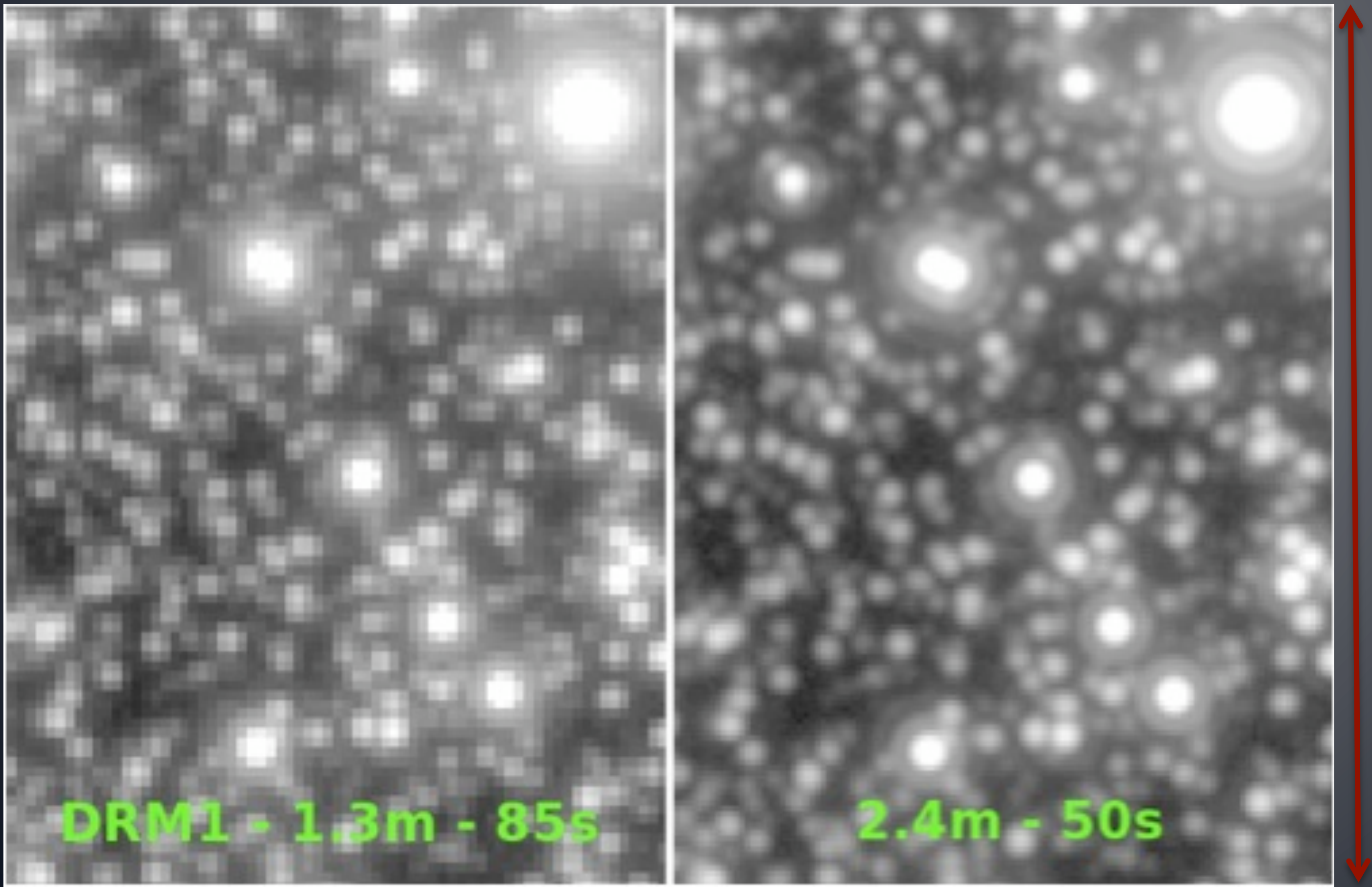




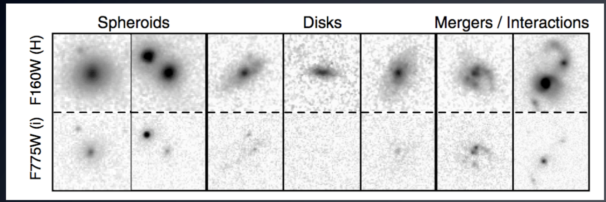
- Space-based imaging needed for high precision photometry of main sequence source stars (at low magnification) and lens star detection
- High Resolution + large field + 24hr duty cycle =>WFIRST
- Space observations needed for sensitivity at a range of separations and mass determinations

NRO 2.4 m design: factor 2 faster survey

Performance of NRO-1 2.4-m compared to SDT WFIRST (DRM1) . The images compare an “equal-duration, equal-area” survey of a Galactic Bulge field (assuming a 2.4-m field of 0.25 sq deg). The total area covered in 15-minute cycles is 2.5-deg, with 7 DRM1 fields or 10 2.4-m fields.

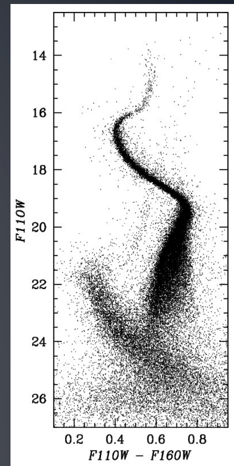


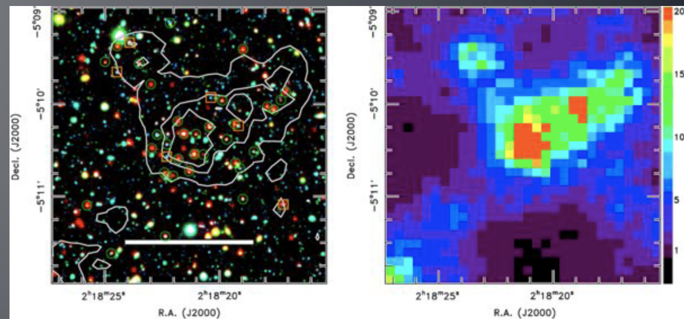
Matthew Penny (OSU)

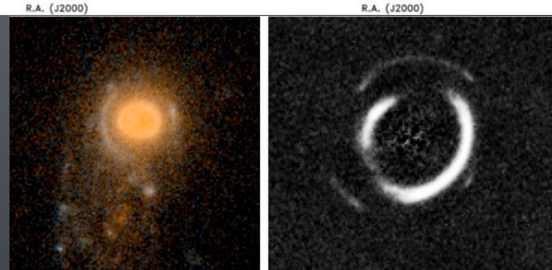


GO & Archive sciences

1. Open Cluster and Star Forming Region IMFs to Planetary Mass
2. Exoplanet via transit and Astrometry
3. High-precision IR CMDs of stellar populations.
4. Quasars as a Reference Frame for Proper Motion Studies (LMC,GB)
5. Proper Motions and Parallaxes of Disk and Bulge Stars (~10μas/yr)
6. White dwarfs.
7. Nearby Galaxies
8. Galaxy Structure and Morphology
9. Evolution of Massive Galaxies
10. Distant, High Mass Clusters of Galaxies
11. Obscured Quasars
12. Strongly Lensed Quasars
13. Strong Lensing
14. High-Redshift Quasars and Reionization
15. Faint End of the Quasar Luminosity Function
16. Probing the Epoch of Reionization with Lyman-α Emitters



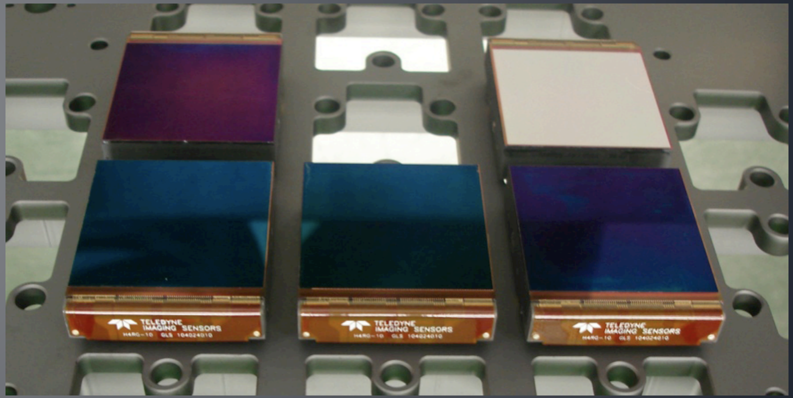




Possible contribution to Euclid/WFIRST from Japan

Hardware (for WFIRST):

- Flight calibration system
- Integral field spectrograph
- Fine guidance sensor
- H4RG development by IRSF
  → long-term characterization



4kx4k H4RG

Non-Hardware:

- Data from a wide-area sky survey performed at the Subaru telescope, designed to complement the Euclid/WFIRST observing program
- Data processing and archiving

summary

- Euclid/WFIRST conduct deep & wide-field optical/IR survey
  - Dark Energy
  - Archival science

- WFIRST complete statistical census of exoplanet
  - Combining with Kepler

- WFIRST has General Observer program-->2.4m may increase GO time

- Japanese contribution is demanded.