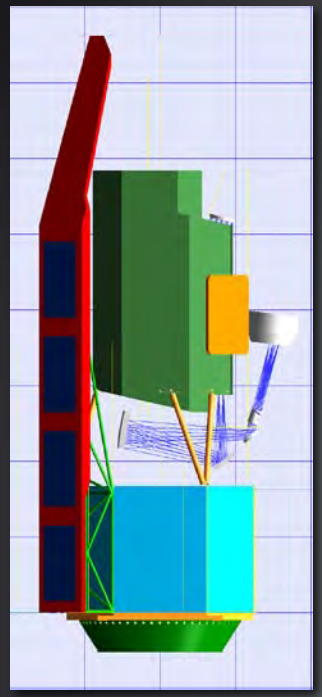
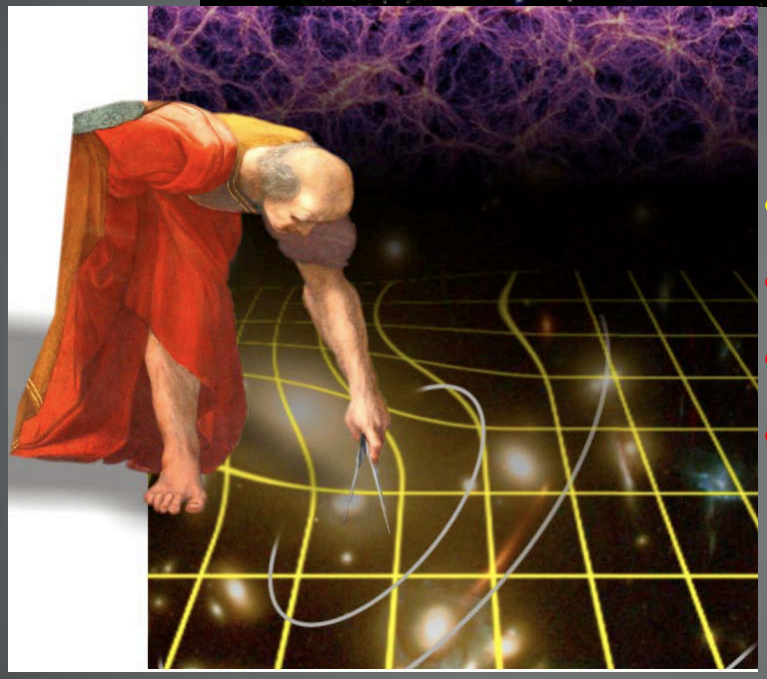
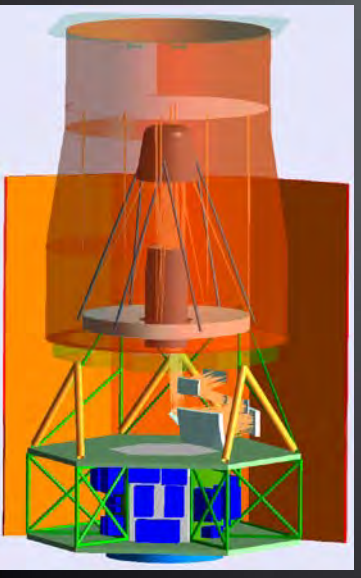
WFIRST/Euclid



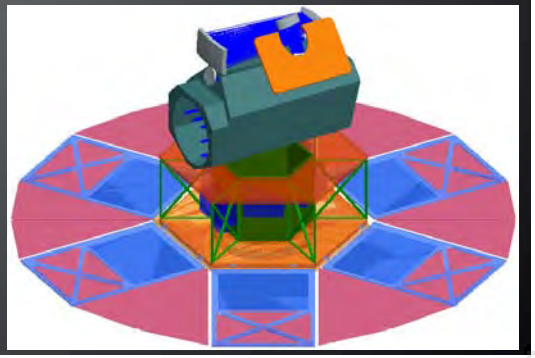
WFIRST
Wide-Field Infra-Red Survey Telescope



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



住　貴宏 (Osaka Univ)
WFIRST SDT member

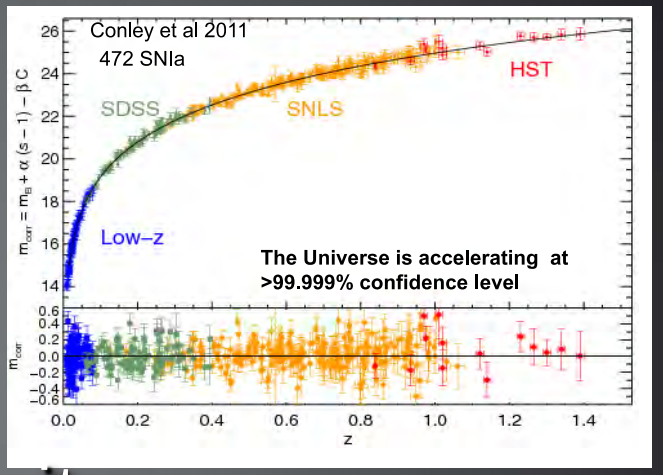


2012/9/27
[すばるHSCサーベイによるサイエンス]
国立天文台

Late 20th century's biggest discoveries

Accelerating expansion of universe

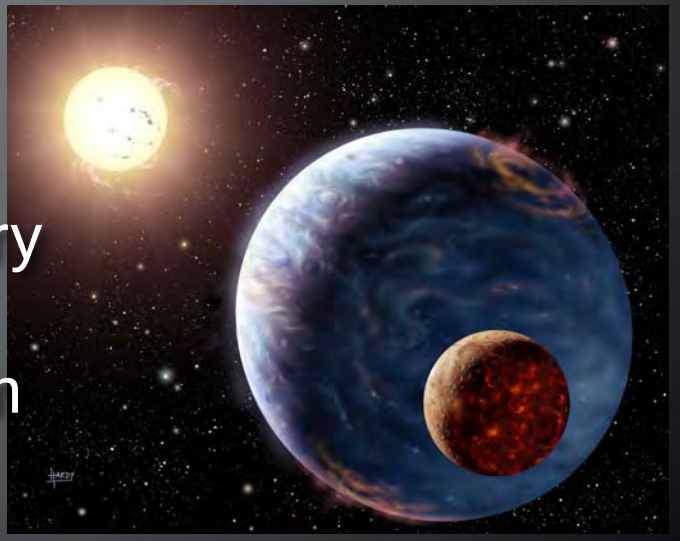
- Cosmic acceleration history via
  - Weak lensing (WL)
  - Supernovae (SN)
  - Baryon Acoustic Oscillation (BAO)
  - Red shift space distortion (RSD)
- Structure growth via WL, RSD
- Test Einstein's gravity and Modified Gravity



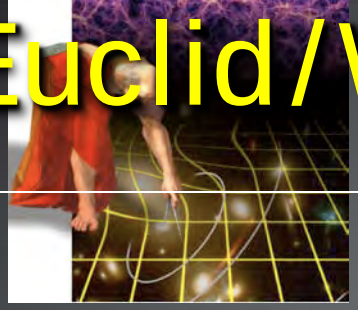
Exoplanets

- 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 (550-900)Im +IR(YJH)Im,Spec

FOV: 0.54deg^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
- (Exoplanet Microlensing)(extended)

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: 0.35-0.6deg^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

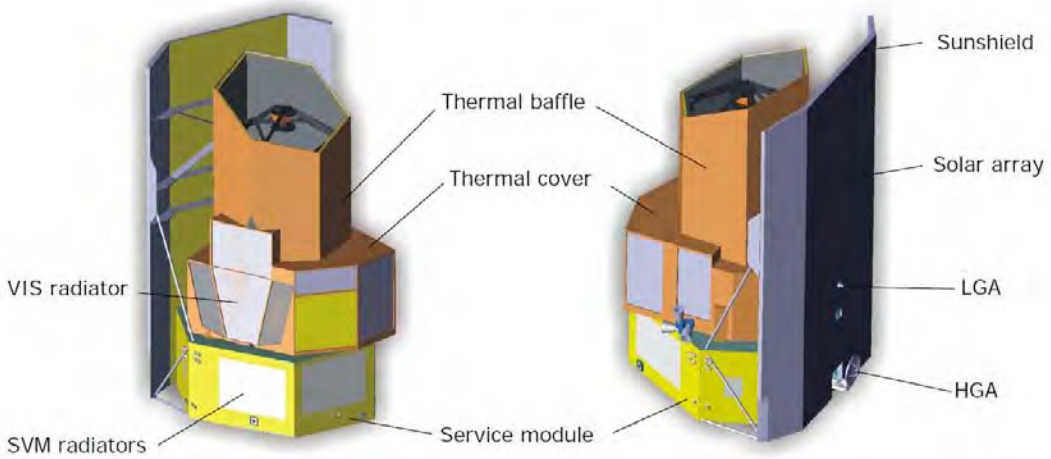
Galactic Bulge 3.4deg^2

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

Euclid: telescope concept

Euclid Consortium

Astrium concept



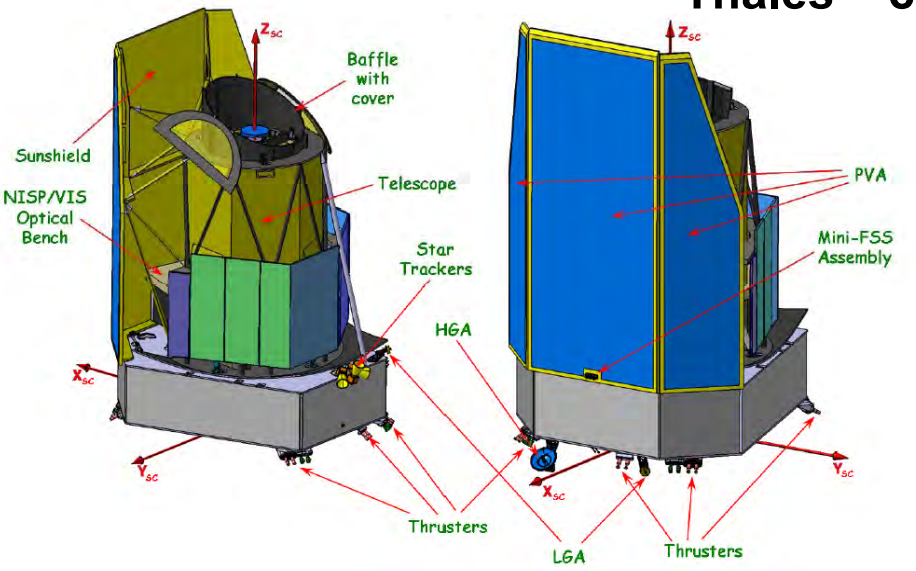
Telescope

- 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

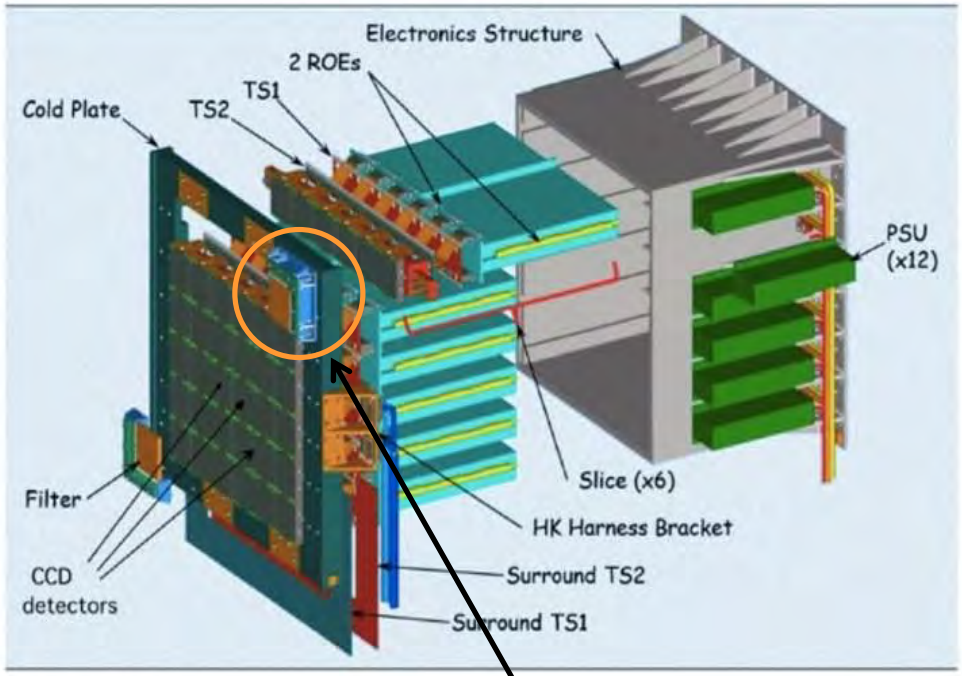
- Fine pointing: Cold Gas + FGS & Gyro
- Slews: Reaction Wheel + Star Tracker & Gyro

VIS Instrument

Euclid Consortium

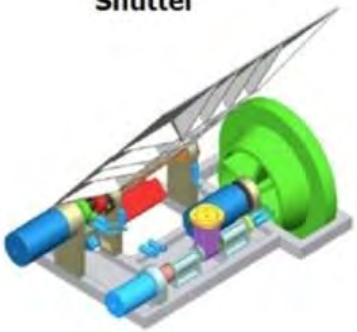
- large area imager – a 'shape measurement machine'
- 36 4kx4k CCDs with 12 micron pixels
- 0.1 arcsec pixels on sky
- bandpass 550-900 nm – narrow band channel
- limiting magnitude for wide survey of magAB = 24.5 for 10σ (extended)
- data volume – 520Gbit/day

COLD



Focal Plane Assembly

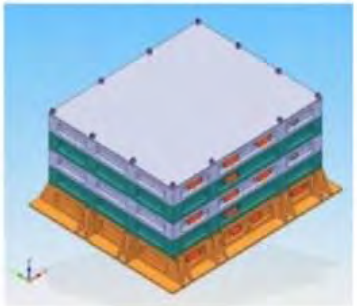
Shutter



Cal Unit

WARM

Power and Mechanisms Control Unit



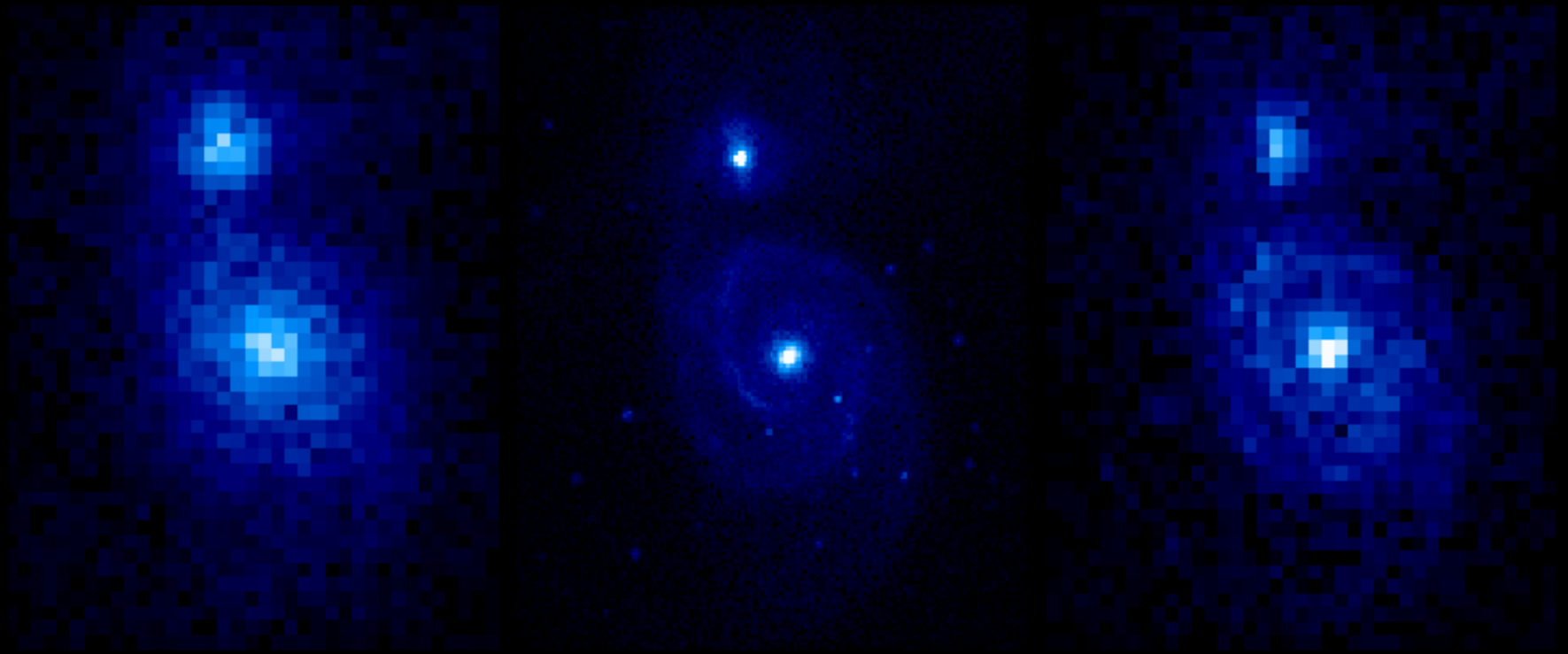
Command and Data Processing Unit

Narrow band filter (color gradient) → Suppressed .

Euclid : SDSS@ 1<z<3

Euclid Consortium

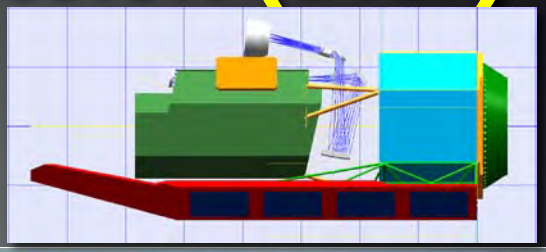
M51



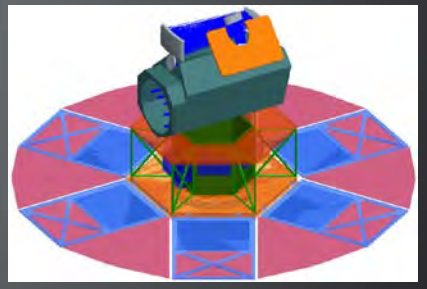
SDSS @ z=0.1 Euclid @ z=0.1 Euclid @ z=0.7

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.

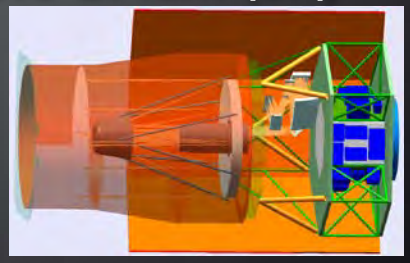
WFIRST design reference mission (DRM)



- 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 (+coronagraph)
  - 0.35 deg^2 FOV (16 H4RG(-10) at 0.13”/pixel)



DRM1 layout

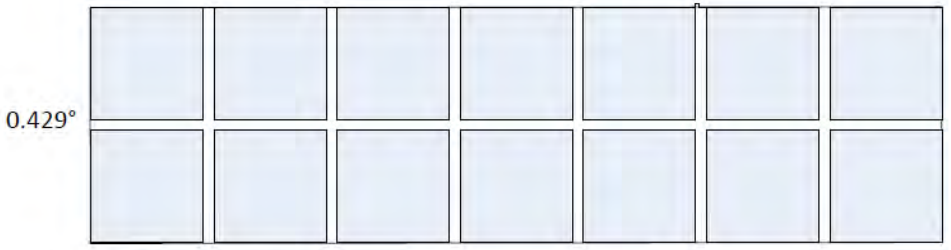
Unobscured optics
provide clean PSF

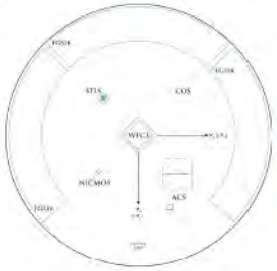
DRM2 Field of view

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

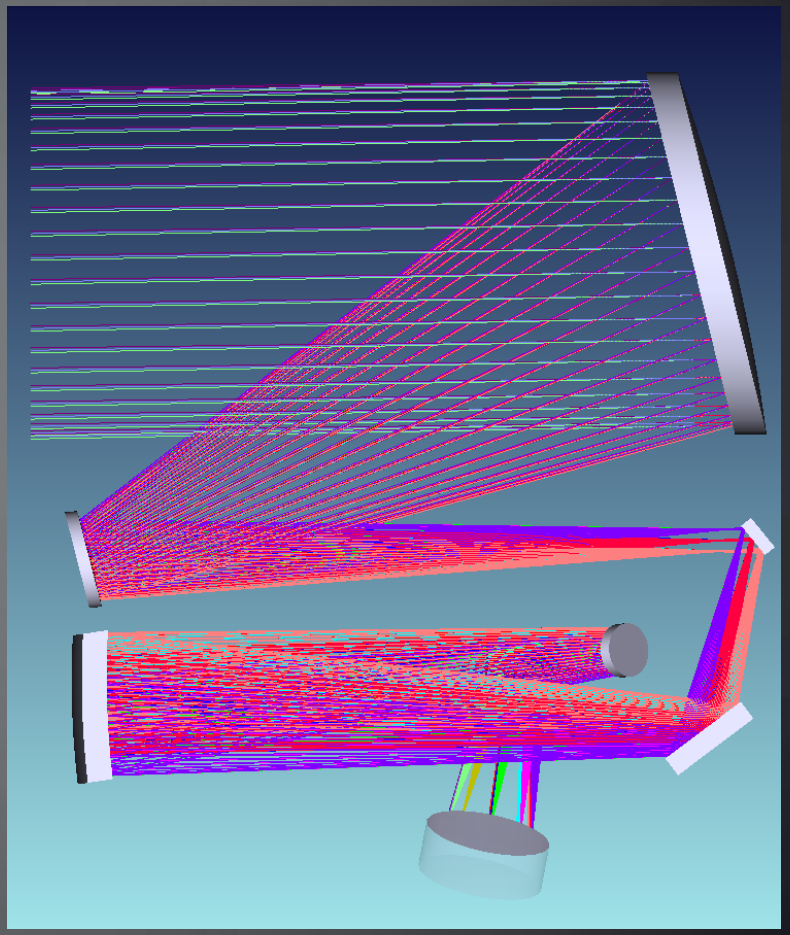




HST [all instruments]

JWST [all instruments]

Moon (average size seen from Earth)



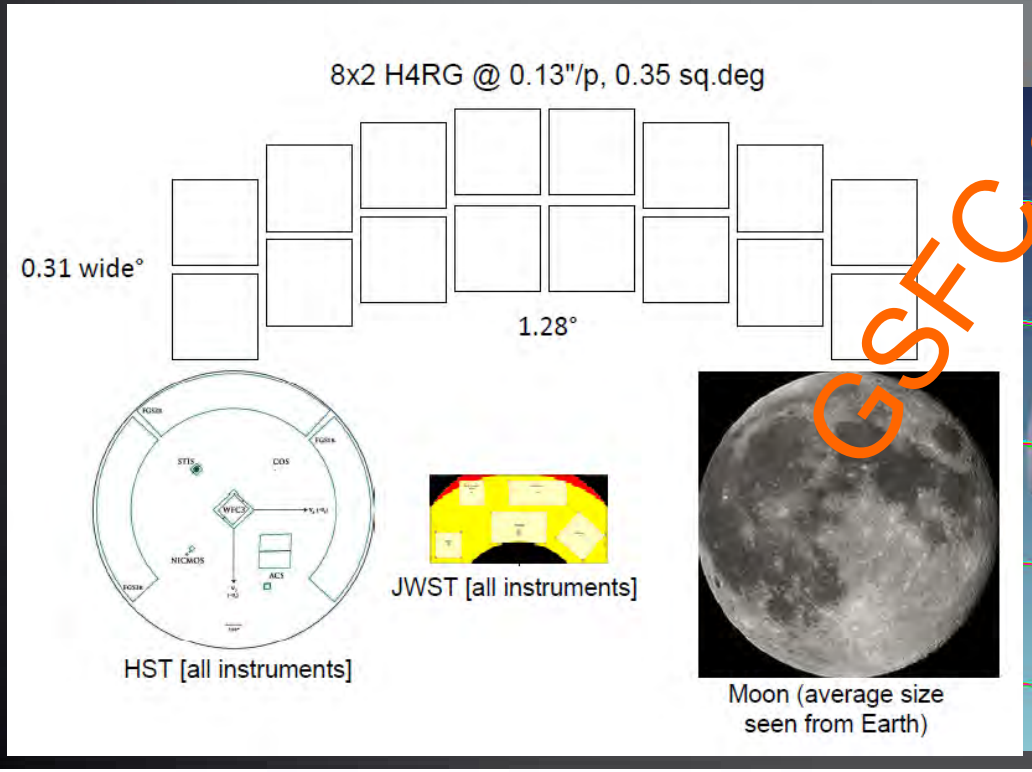
NRO-1 2.4m design

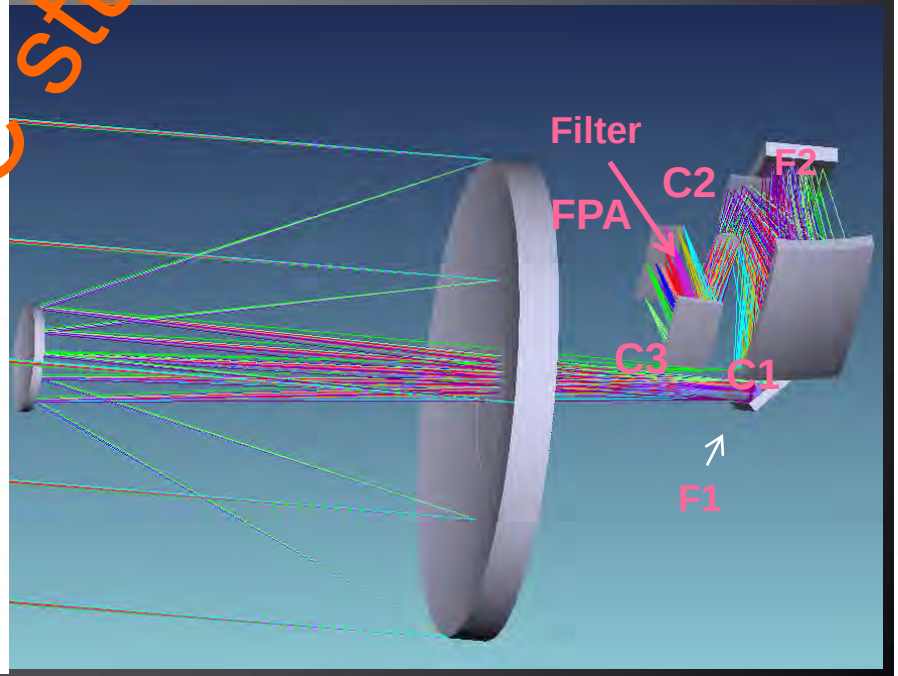
Preliminary Instrument Design:

- Based on existing telescope primary and secondary mirrors <u>without changes</u>
- 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

<u>Potential Payload Overview:</u>

- 2 wide field instruments
2 small, finer sampled instruments

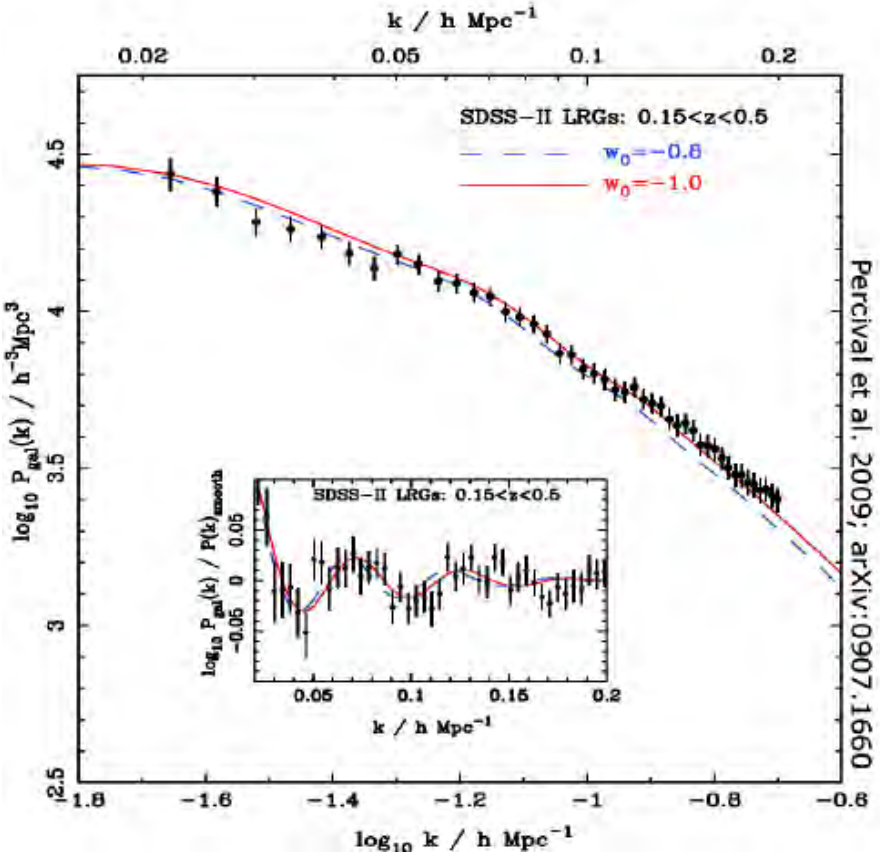


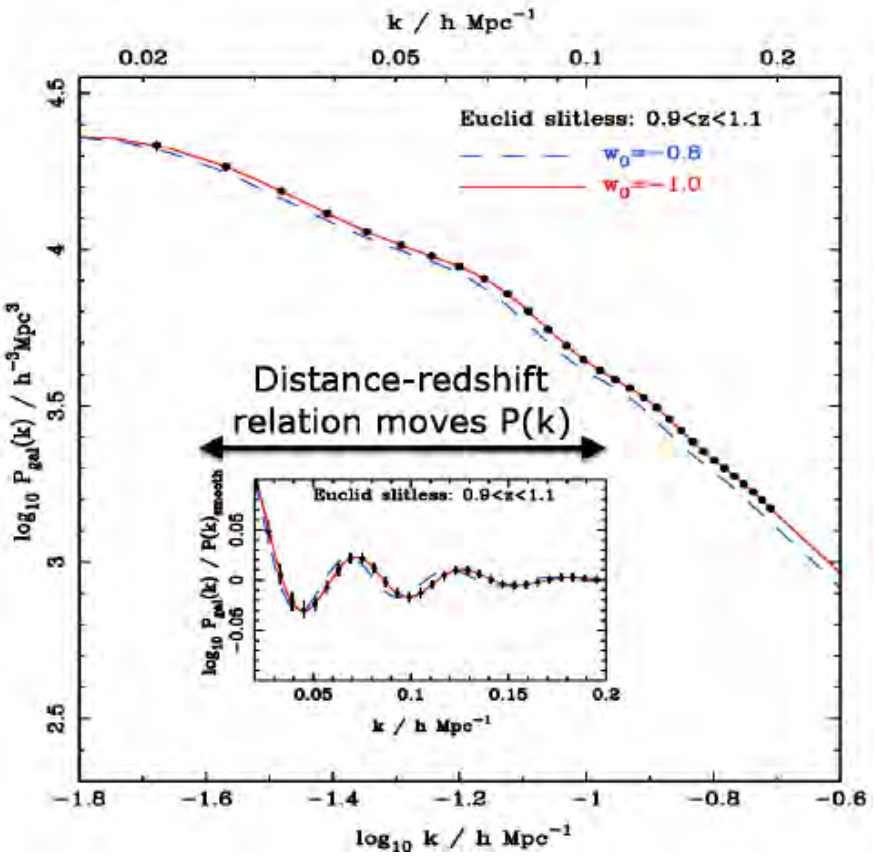


Euclid GC predicted performances

Euclid Consortium

Reconstructed galaxy power spectrum





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.

Sky survey strategy includes:

- Instrument calibration with specific targets
- Wide and Deep fields

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

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

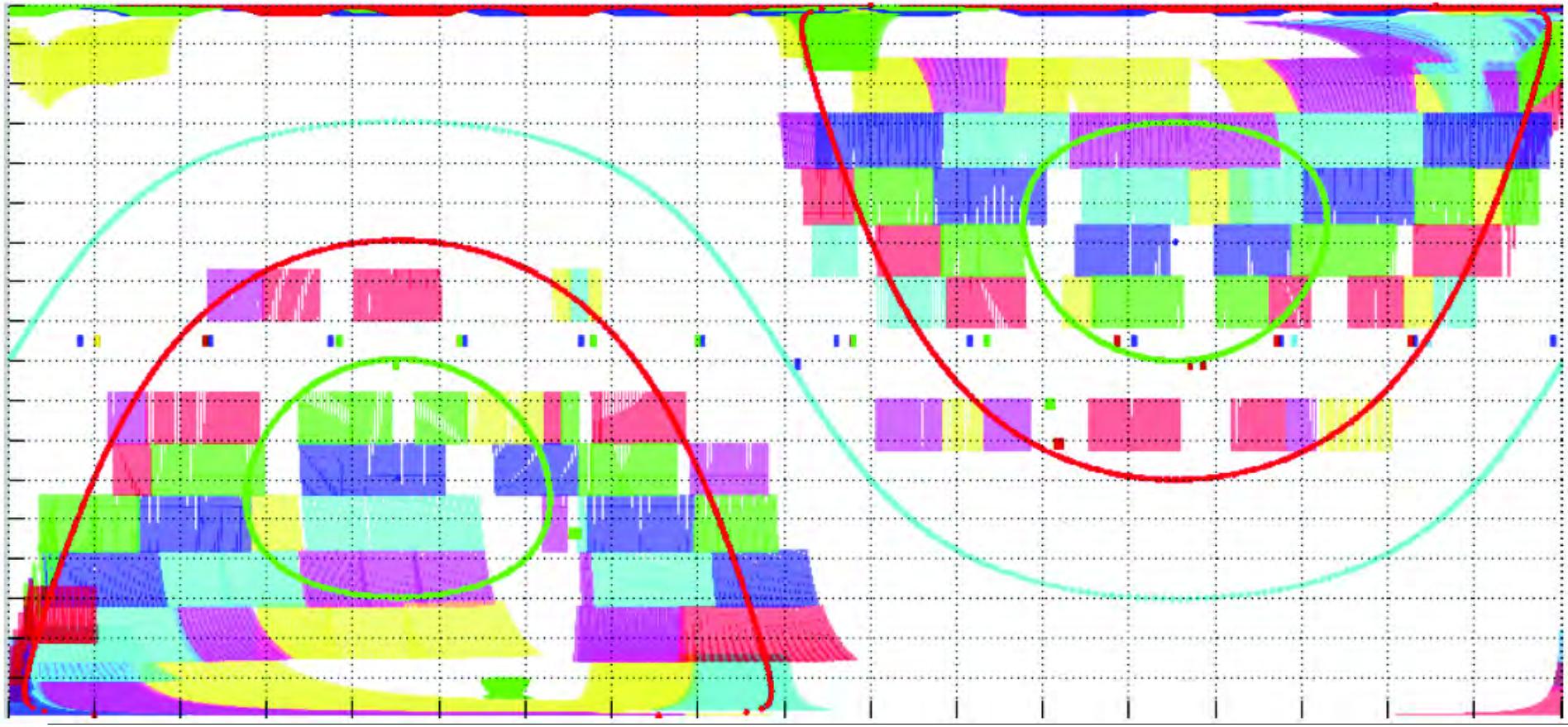
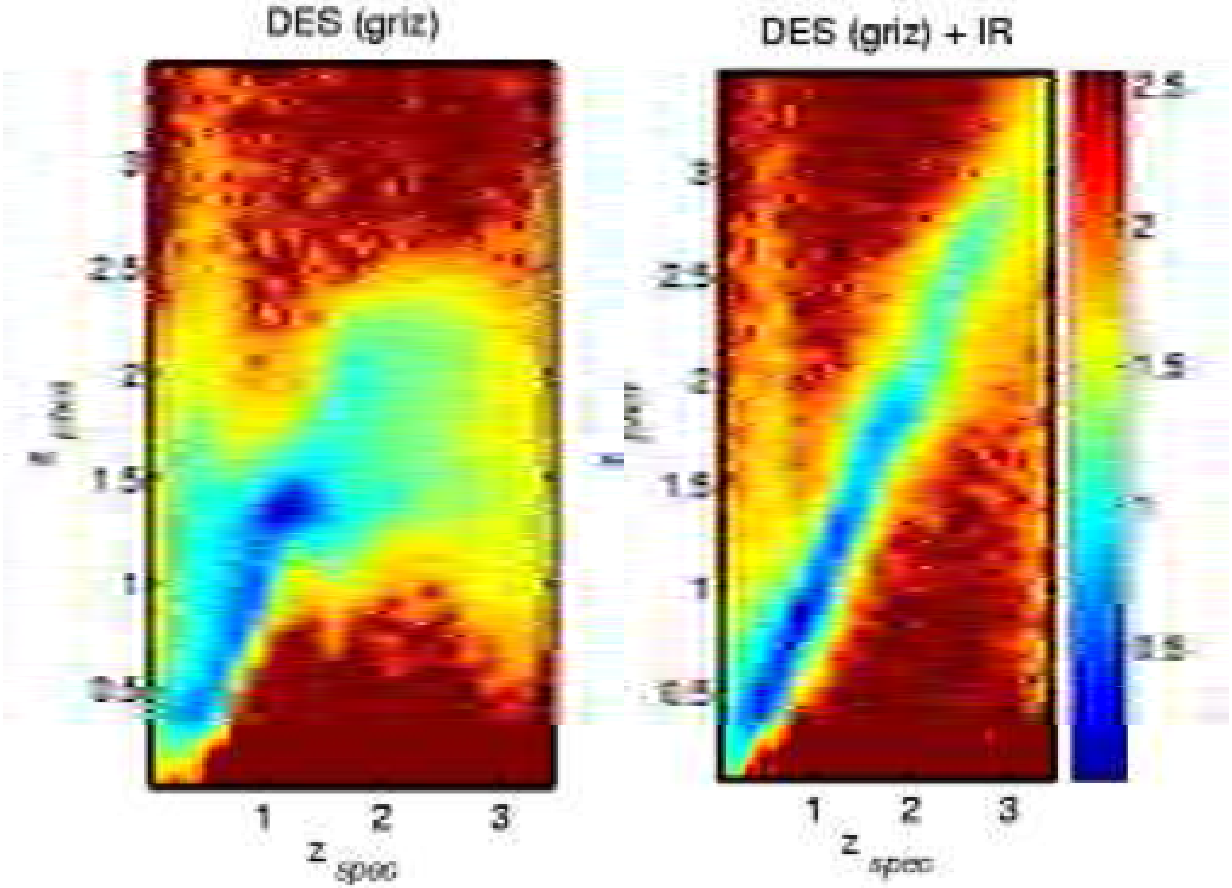


Photo-z: DES + Euclid data

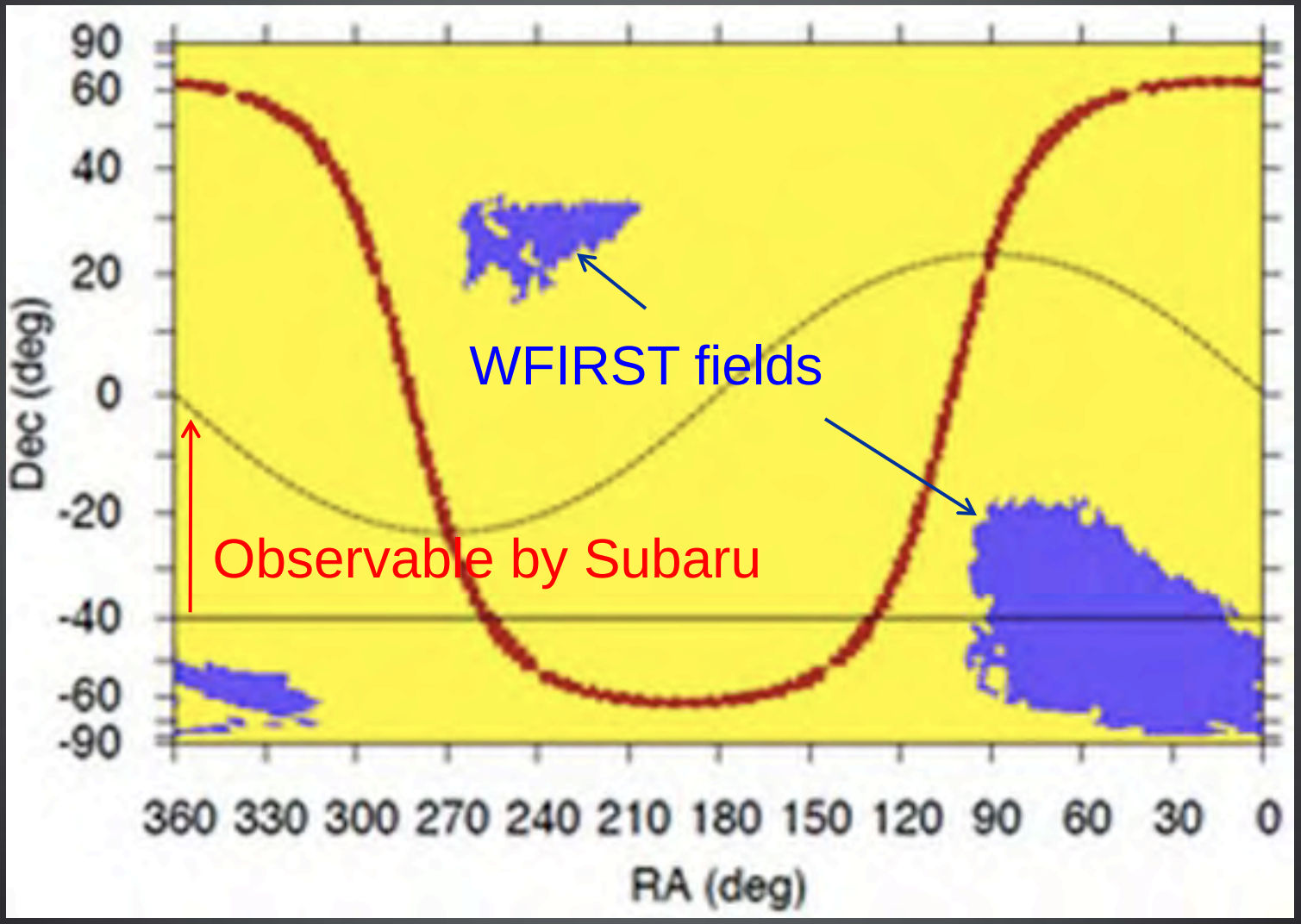


al data from ground-based telescopes

HSC-Euclid 関係（宮崎、高田）

- ESAのEuclid衛星計画：
  - 全天撮像・分光サーベイ, 2020年打ち上げ（予定）, €800M (確保)、1.2m望遠鏡、可視光1filter(V+I+Z)、近赤3 filters：Y, J, H
  - サイエンス：Dark energy, Dark matter (重力レンズ、BAO)
  - H=24AB for Wide, H=26AB for Deep (北天頂領域25 sq. degrees)
- 地上望遠鏡サーベイのパートナーが必要(for photo-z)
  - 南天: Dark Energy Survey (CTIO4m)と合意。LSSTも想定。
  - 北天: PS2, WHT (4m), Subaru HSCが候補
  - 6月末、Euclid Leading Scientist (PIに相当)Yannick Mellier氏から、EuclidのためのHSCサーベイ(6000 sq. degs) の可能性についての打診（200晩相当）
  - 林台長から、1年後に何らかの返事をするとの回答書を送付
- 今後１年間をかけSAC主導で議論の場を設け、検討を行う
  - HSC-Euclid検討班の立ち上げ（10月中、宮崎、高田を中心にして）
  - HSC-Euclid検討研究会（仮称）の開催（12月中）
  - すばるUMでの議論（2013年1月15-17日）
  - 議論のポイント：(1) 日本コミュニティーがEuclidのデータの価値をどのように評価するか？(2)いずれ公開されるEuclidデータは公開されるが、すばるの夜数を投資し、最初から国際共同研究に参加する価値はあるか？

WFIRST fields



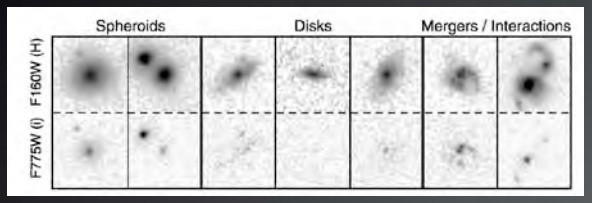
WFIRST Survey

HLS:

>1000 quasars at z>7 (also expect at z>10)

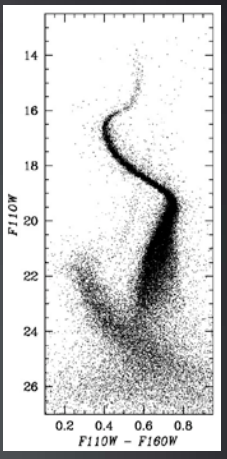
Super Novae:

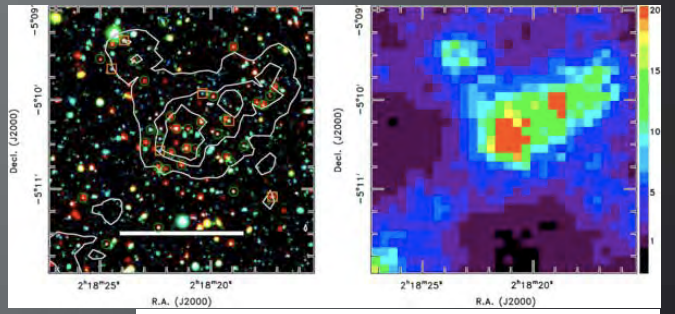
6.48 deg^2 monitored to *z* = 0.8,
1.8 deg^2 monitored to *z* = 1.7,
1800 spectroscopically confirmed Type Ia supernovae out to redshift z = 1.7.

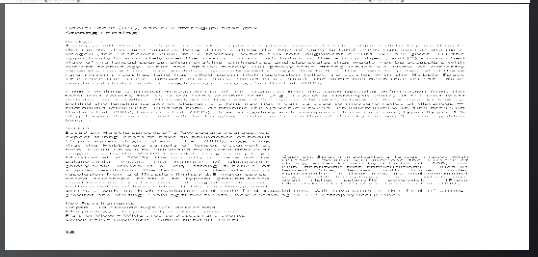


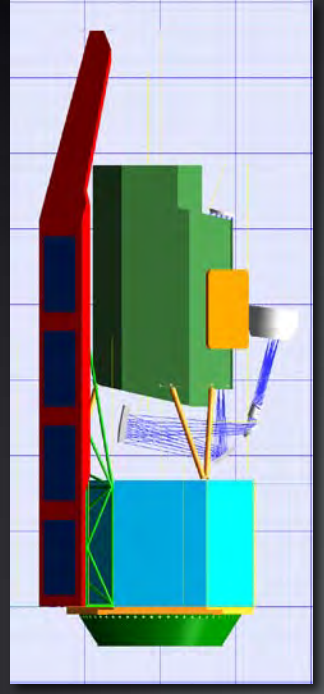
GO & Archive sciences

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



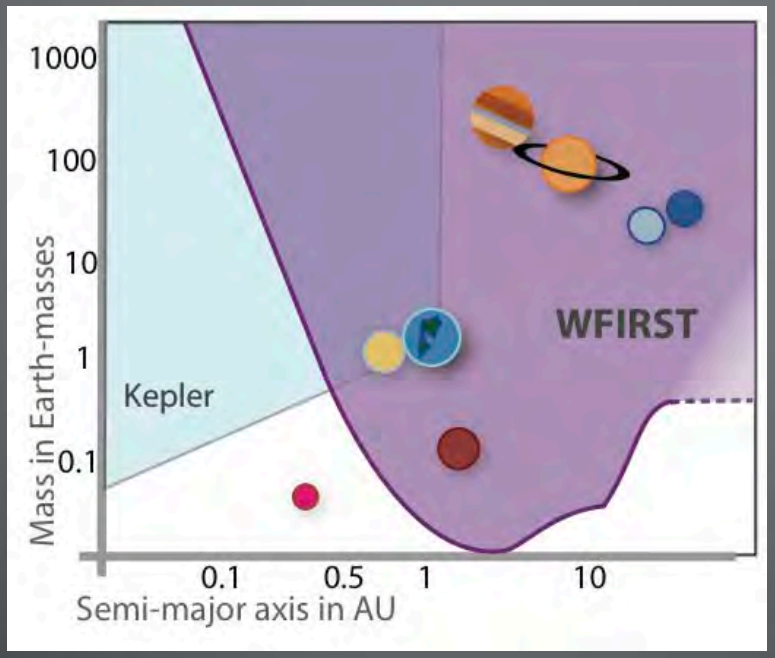




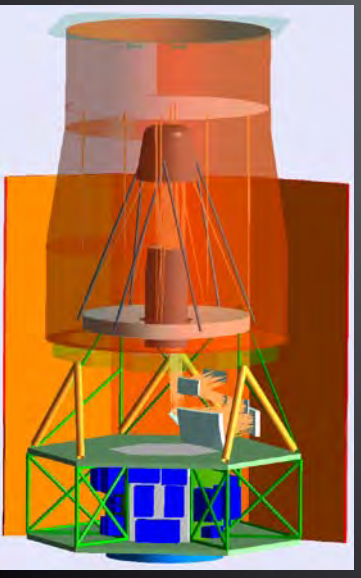


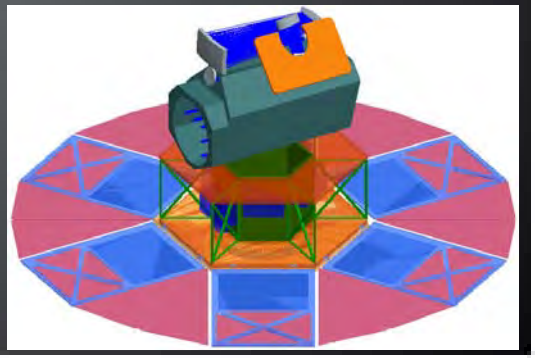
Space Microlensing Exoplanet Survey with

WFIRST
Wide-Field Infra-Red Survey Telescope

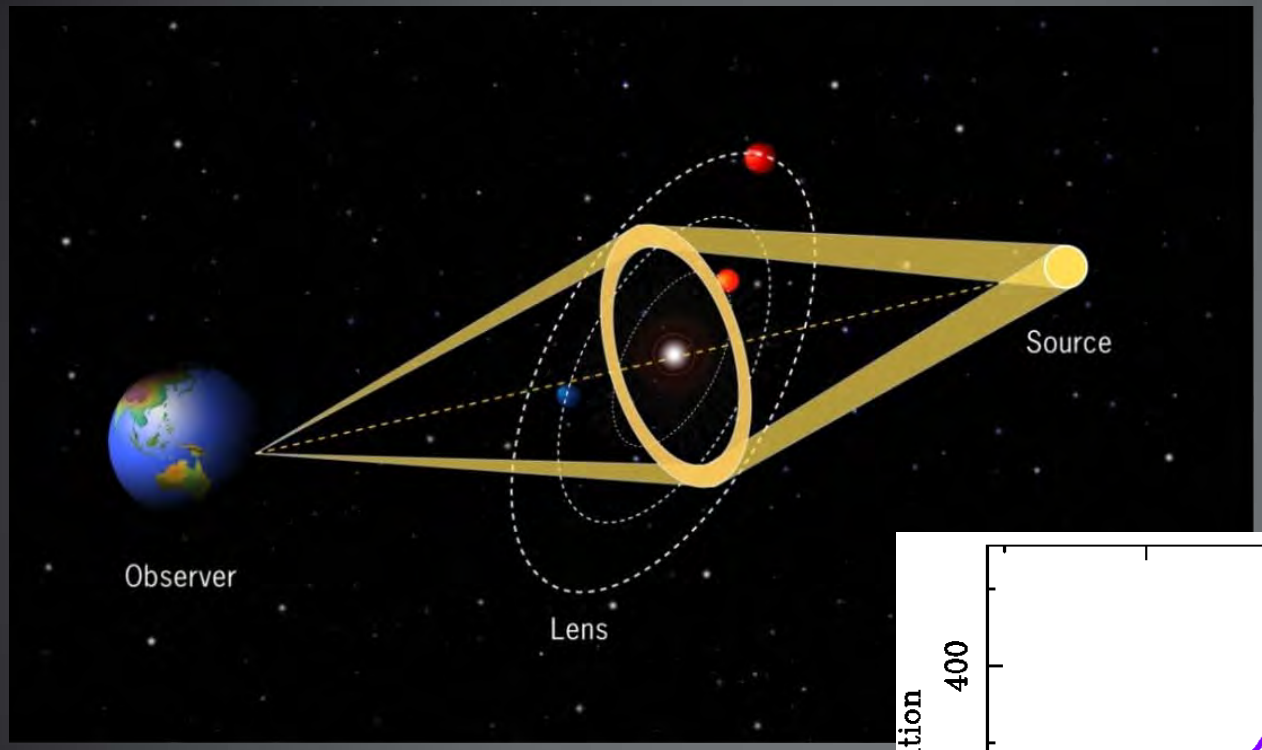


- Dark Energy
- Exoplanet Microlensing
- Near Infrared Sky Survey
- Guest Investigator Program



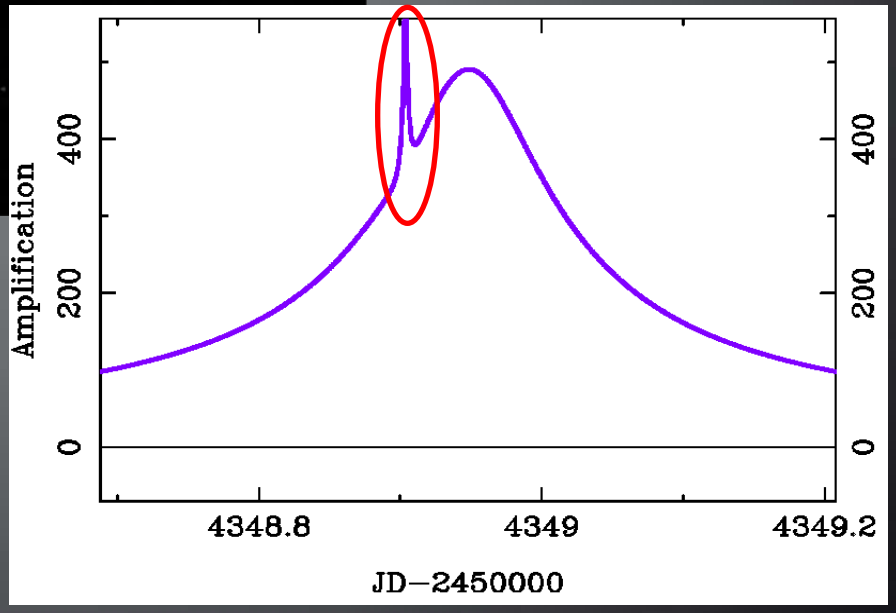


planetary microlensing



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

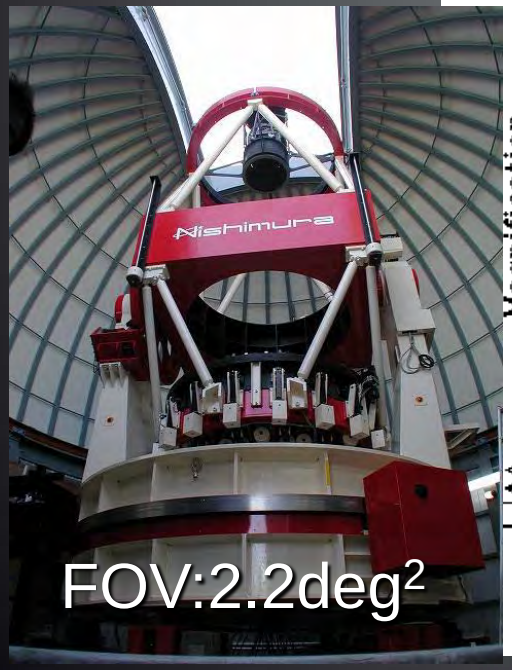
Sensitive to Cold planets outside of snowline (~3AU)



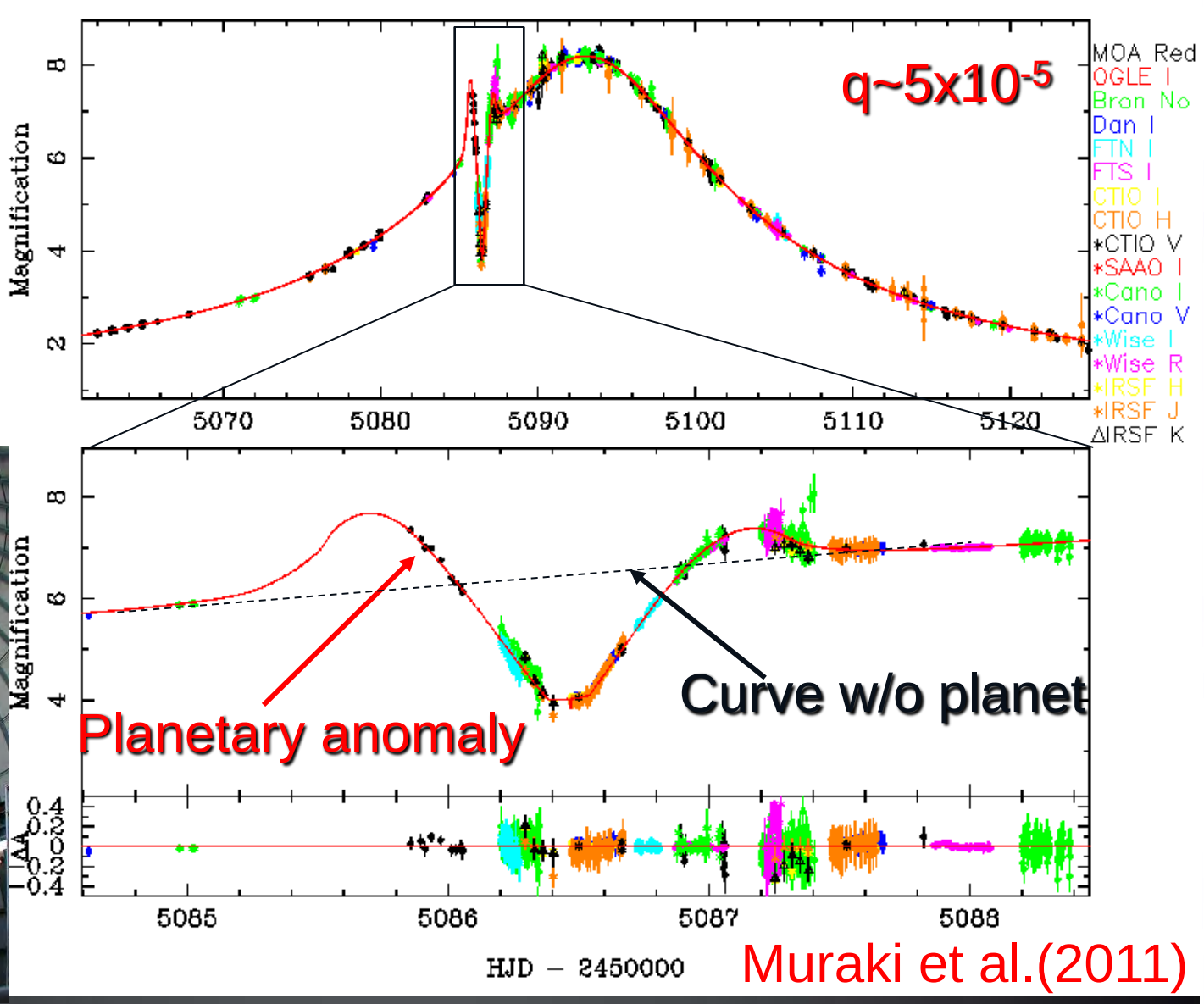
Survey & follow-up from Ground

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

MOA-II 1.8m



FOV:2.2deg^2

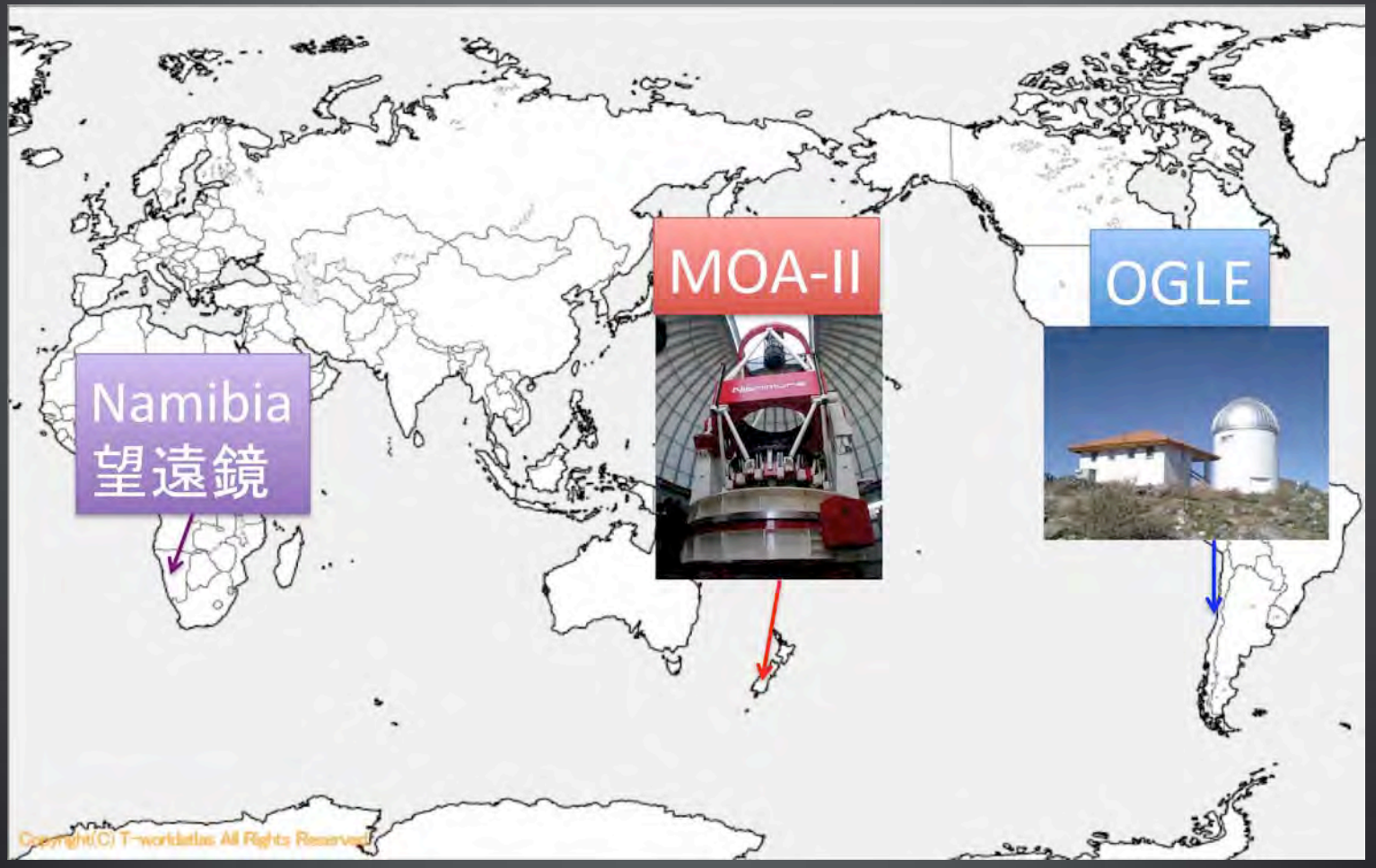


Muraki et al.(2011)

Next generation 24h survey network

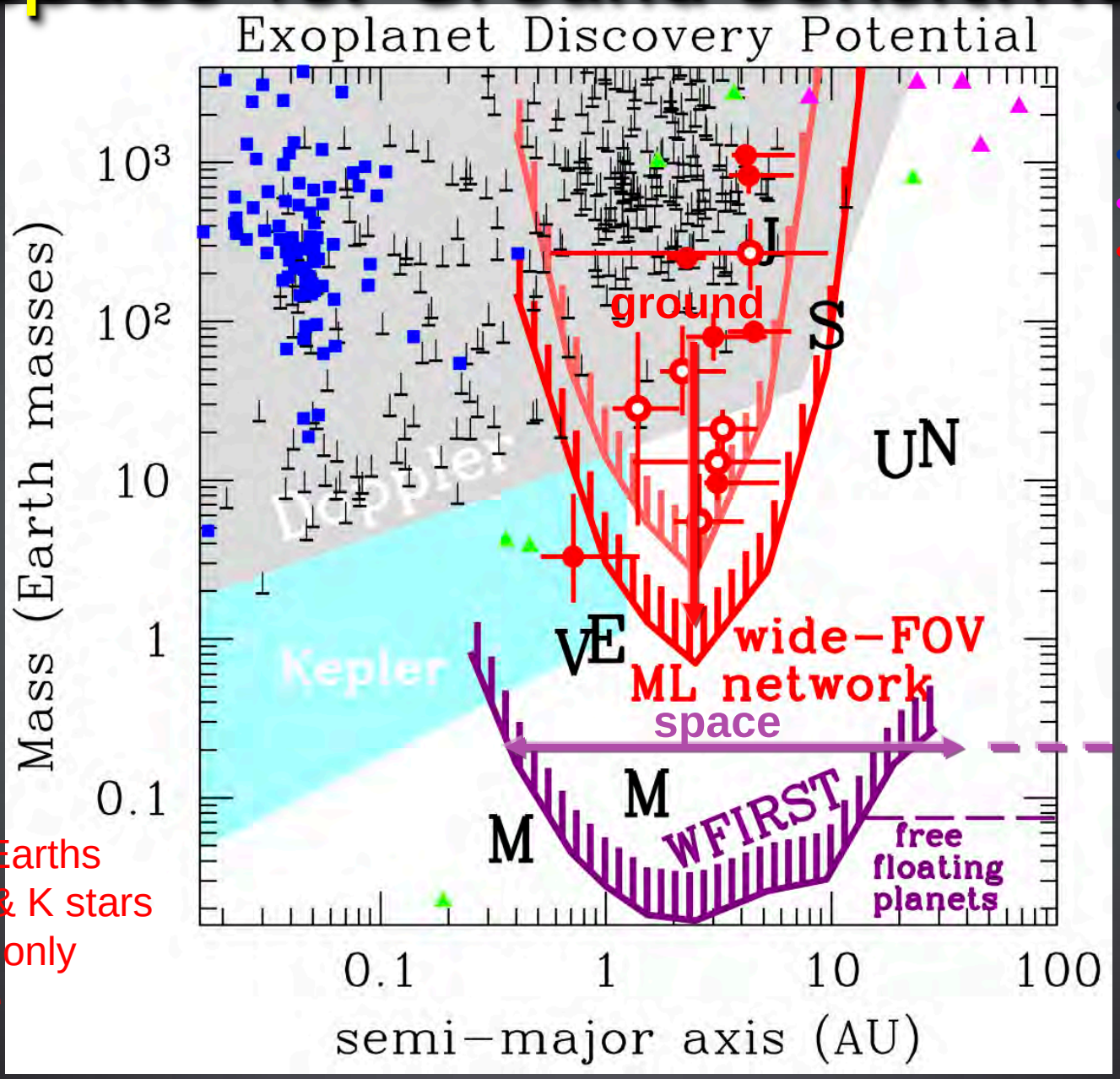
新MOA-III 望遠鏡
口径： 1.5m
FOV: 4.8平方度

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



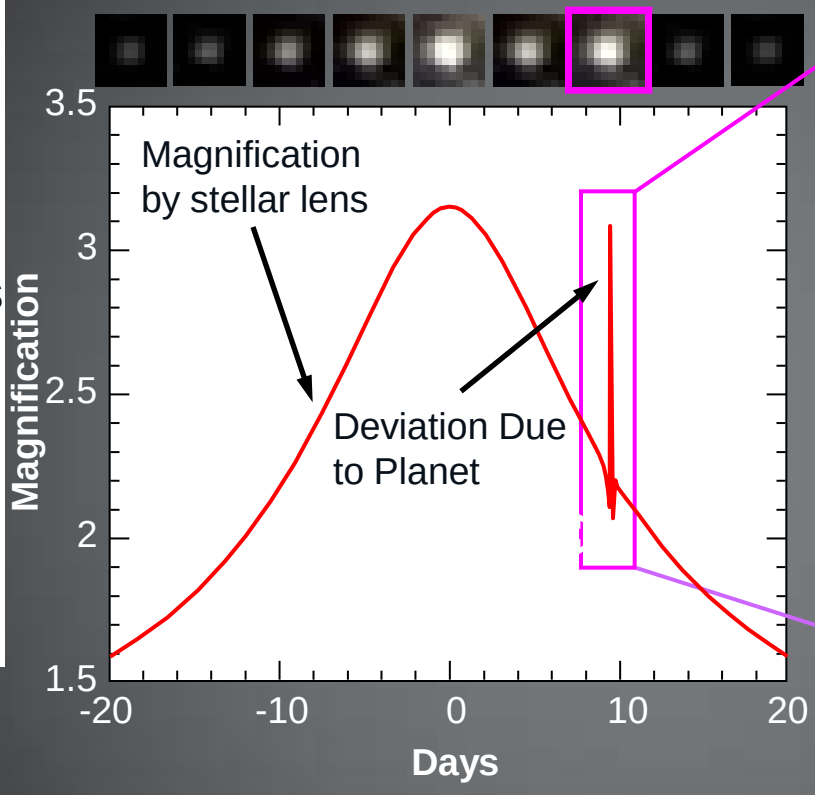
24時間連続観測によって、追観測なしで惑星検出を約17個/年に大幅に上げる

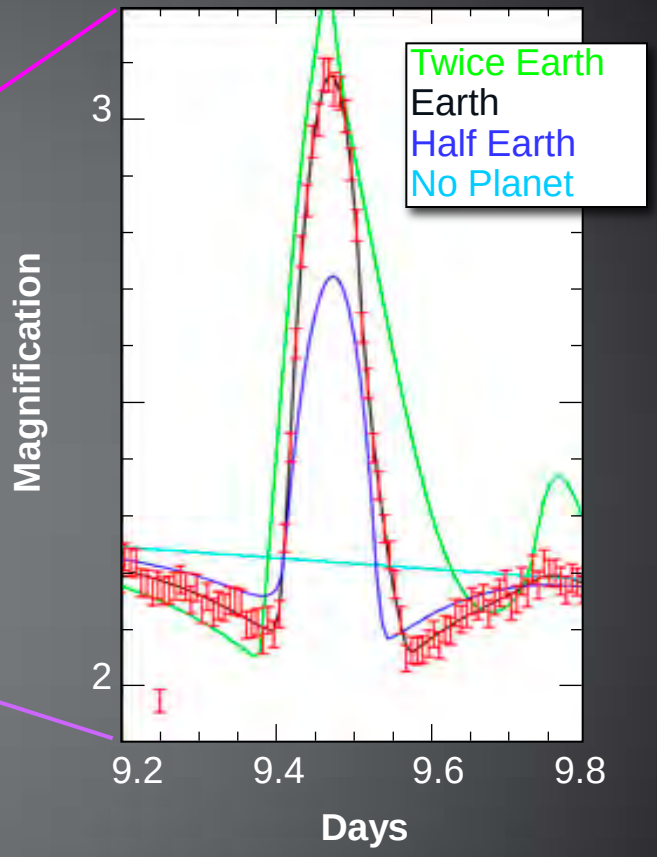
Space vs. Ground Sensitivity



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 x6

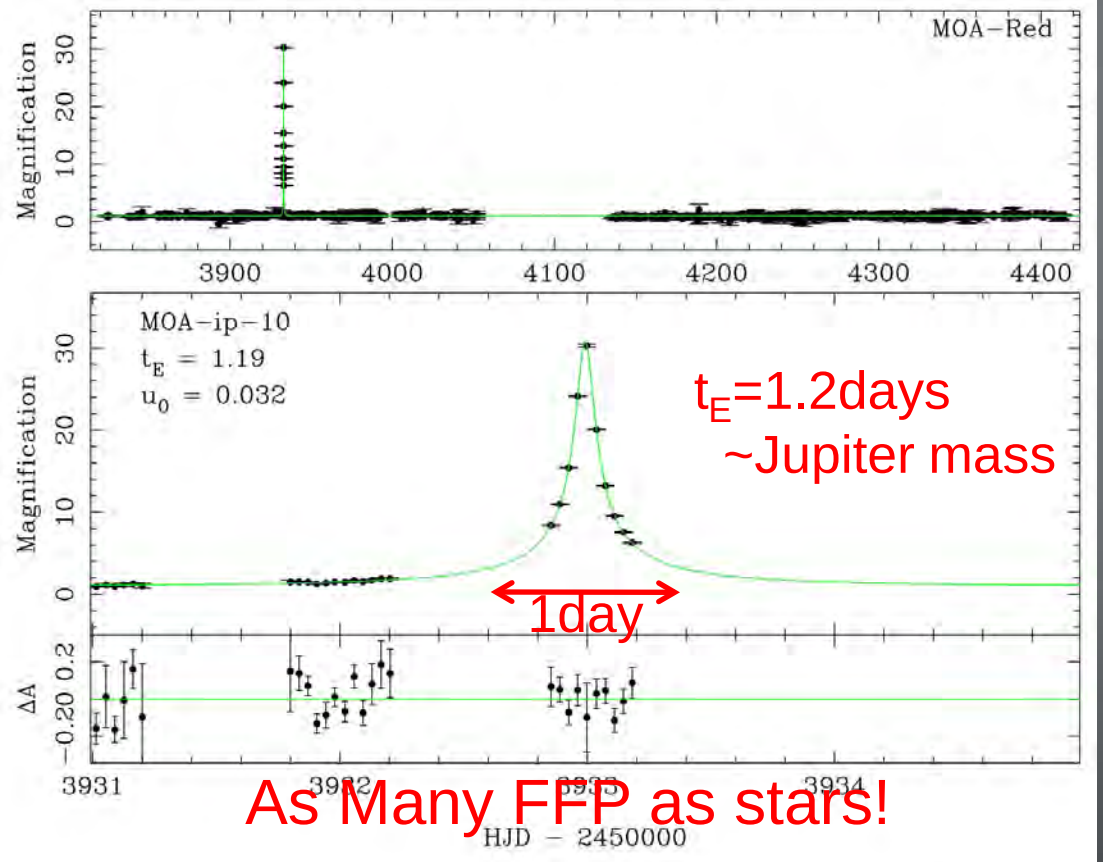
Detailed fitting to the photometry yields the parameters of the detected planets.

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



t_E=1.2days
~Jupiter mass

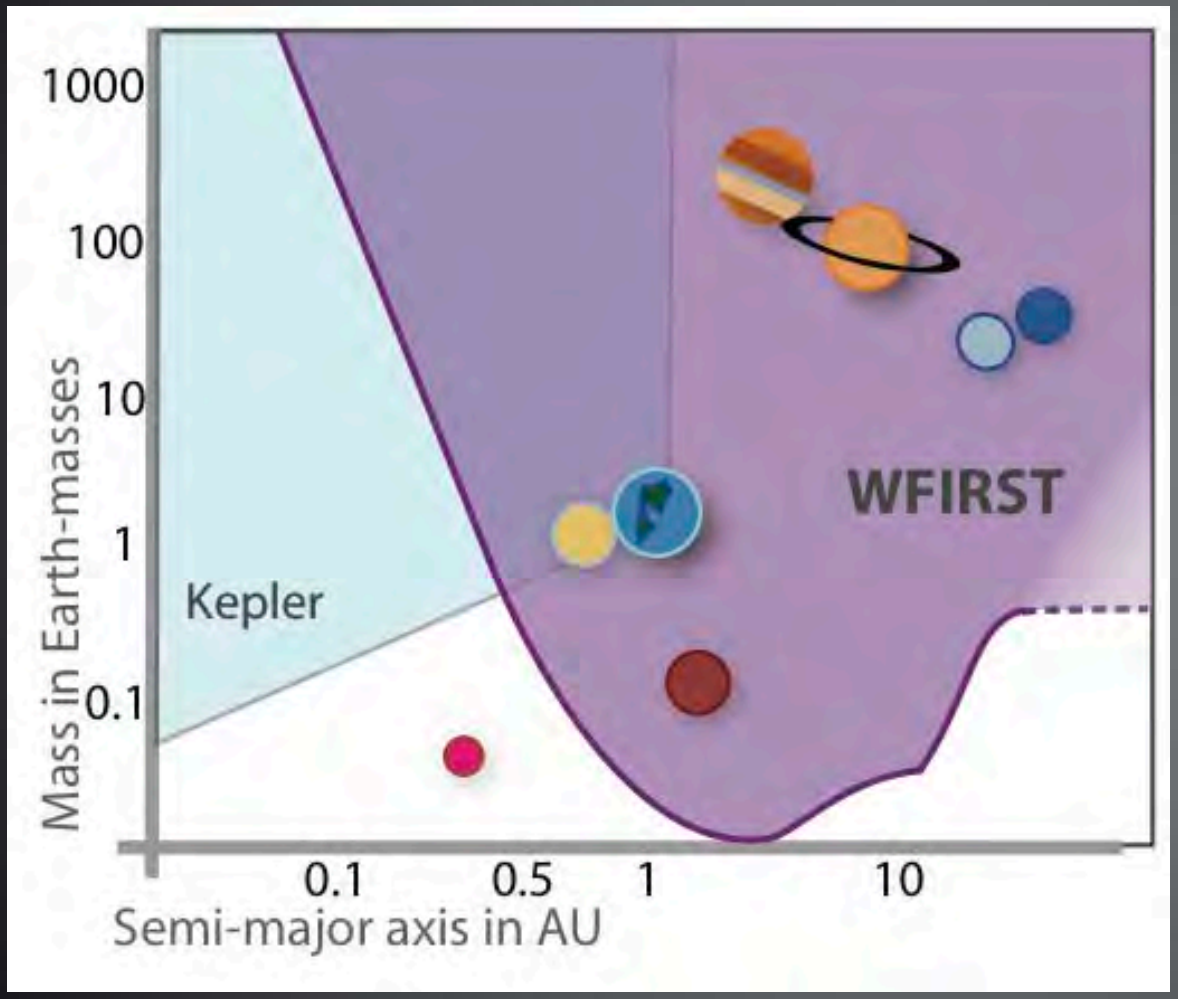
1day

As Many FFP as stars!

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

TS et al. 2011

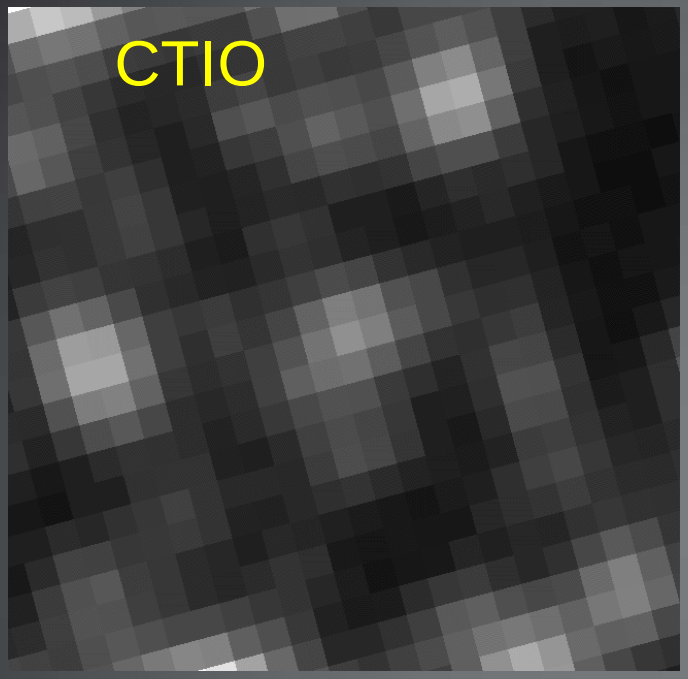
Kepler and WFIRST

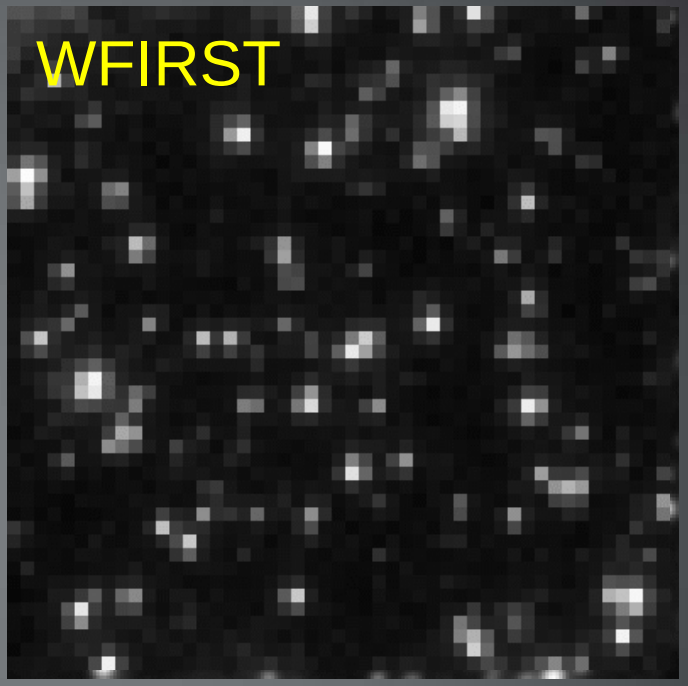


- 3000 bound planet
  - 200 (< 1 $M_\oplus$)
- 2000 free-floating planet
  - 100 (< 1 $M_\oplus$)

Complete the census of planetary systems in the Galaxy

Ground-based confusion, space-based resolution

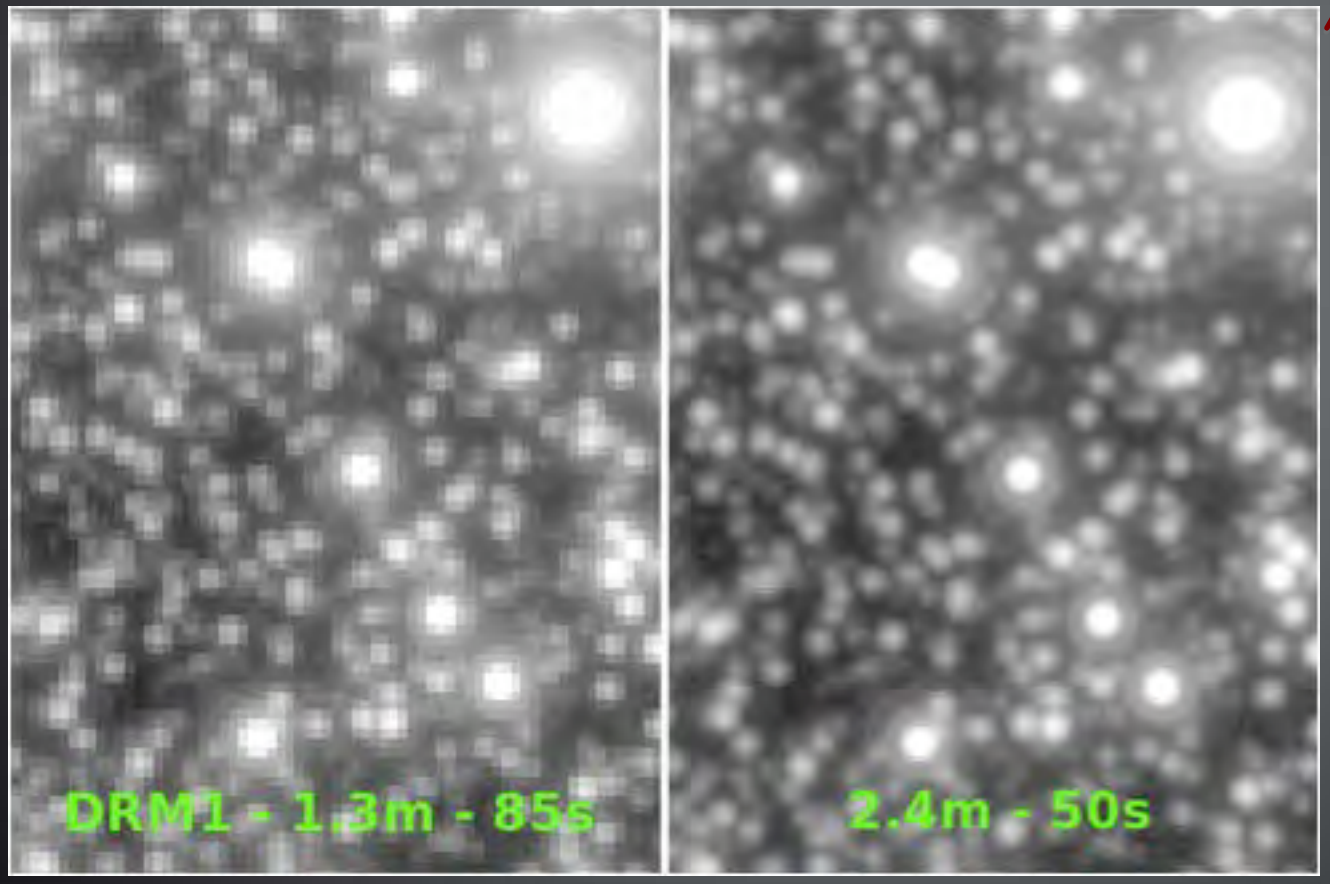


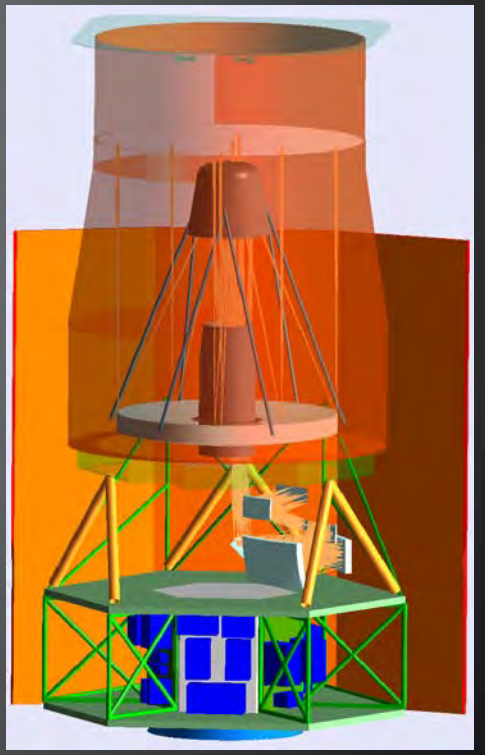


- Space-based imaging needed for high precision photometry of main sequence source stars (at low magnification) and lens star detection
- High Resolution + large field + 24hr duty cycle =>WFIRST
- Space observations needed for sensitivity at a range of separations and mass determinations

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)

Possible contribution to Euclid/WFIRST from Japan

Non-Hardware (Euclid/WFIRST)

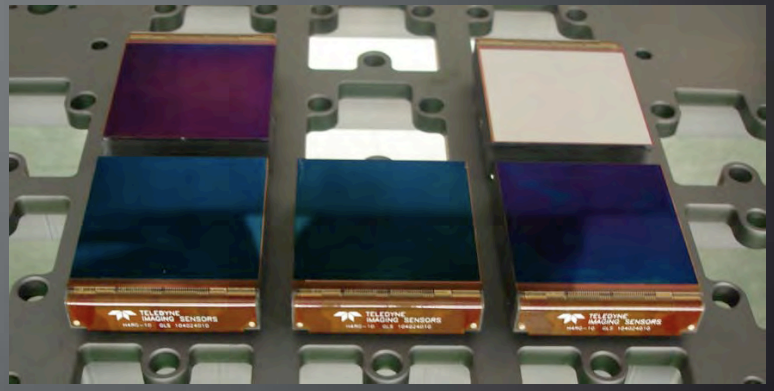
- Data from a wide-area sky survey by Subaru HSC, designed to complement the Euclid/WFIRST observing program
- Data processing and archiving

Hardware (for WFIRST):

- Flight calibration system
- Integral field spectrograph
- Fine guidance sensor
- Coronagraph
- H4RG development by Namibia tel./IRSF

→ long-term characterization

4kx4k H4RG



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 contributions are demanded.
  - HSC data for Euclid/WFIRST
  - Hardware for WFIRST