Euclid-WFIRST complementarity

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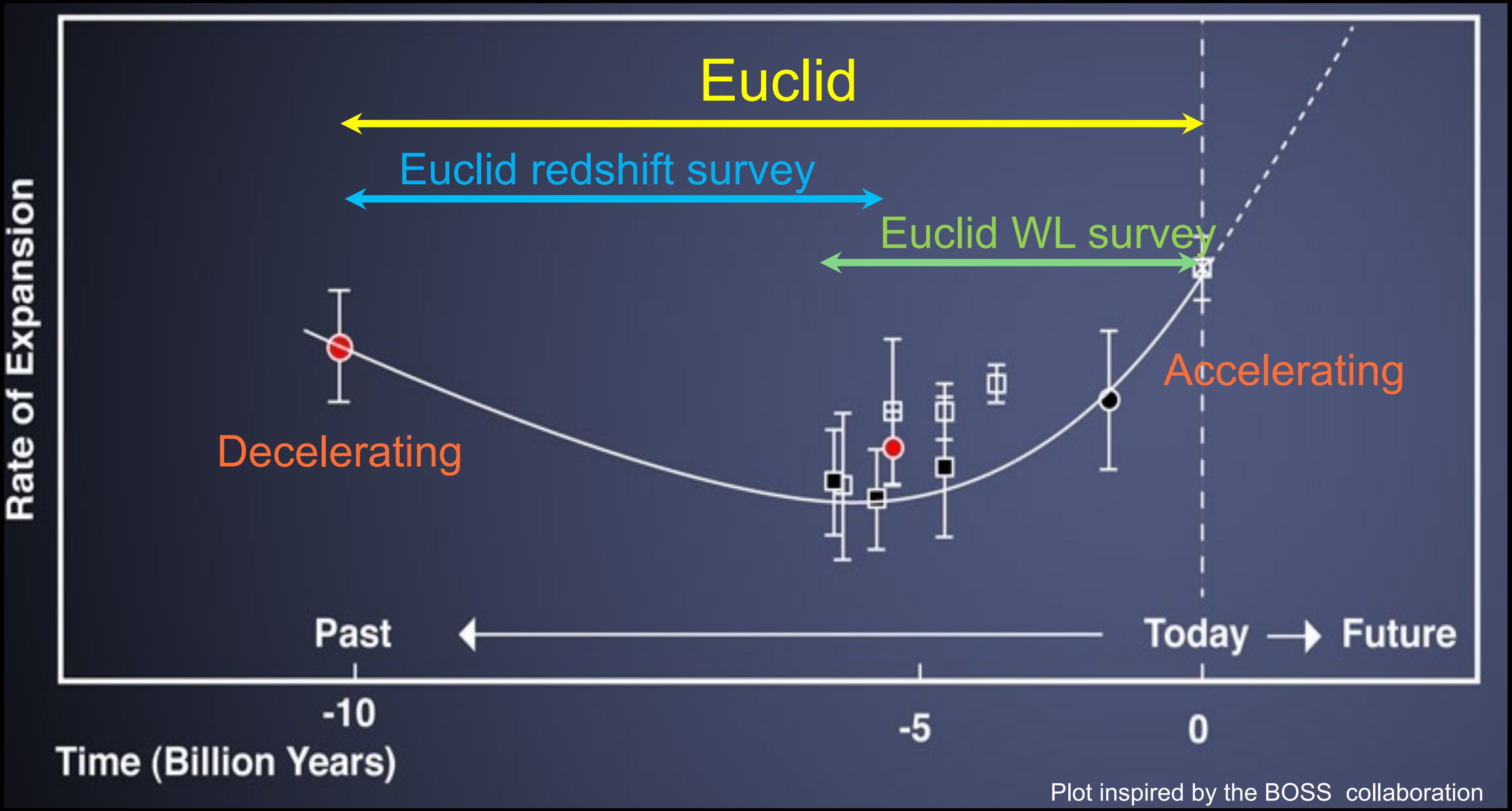
On behalf of the Euclid Consortium

Euclid Primary Objectives: the Dark Universe

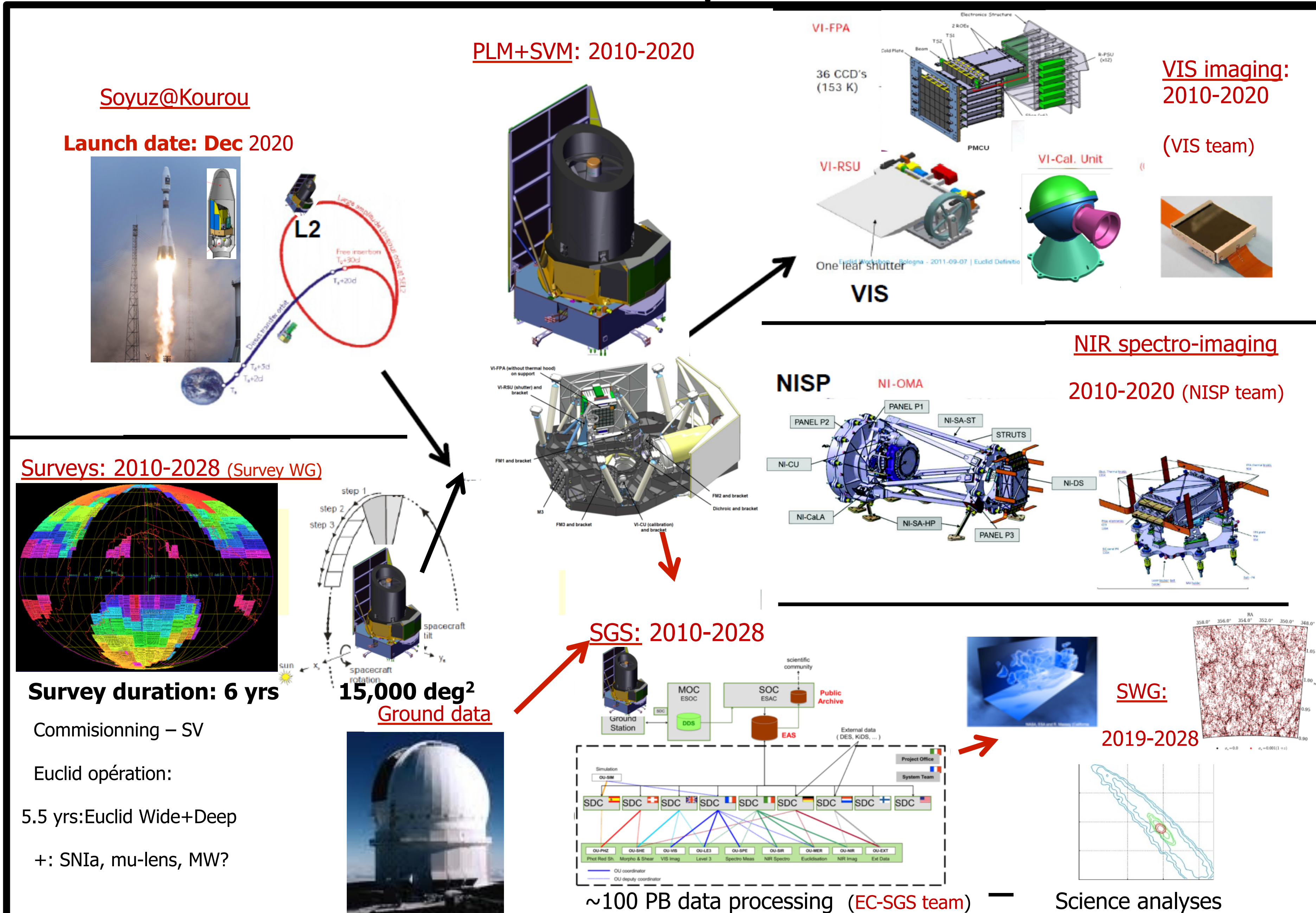
- Understand the origin of the Universe's accelerating expansion
- Probe the properties and nature of Dark Energy and Gravity,

- Probe the effects of Dark Energy, Dark Matter and Gravity by:
  - Using at least 2 independent but complementary probes (5)
  - Tracking their observational signatures on the
    - Geometry of the universe: Weak Lensing (WL), Galaxy Clustering (GC)
    - Cosmic history of structure formation: WL, Redshift-Space Distortion (RSD), Clusters of Galaxies (CL)
  - Controling systematics to an unprecedented level of accuracy.

Euclid will explore the dark universe and the DM-dominated / DE-dominated transition period



The ESA Euclid space mission

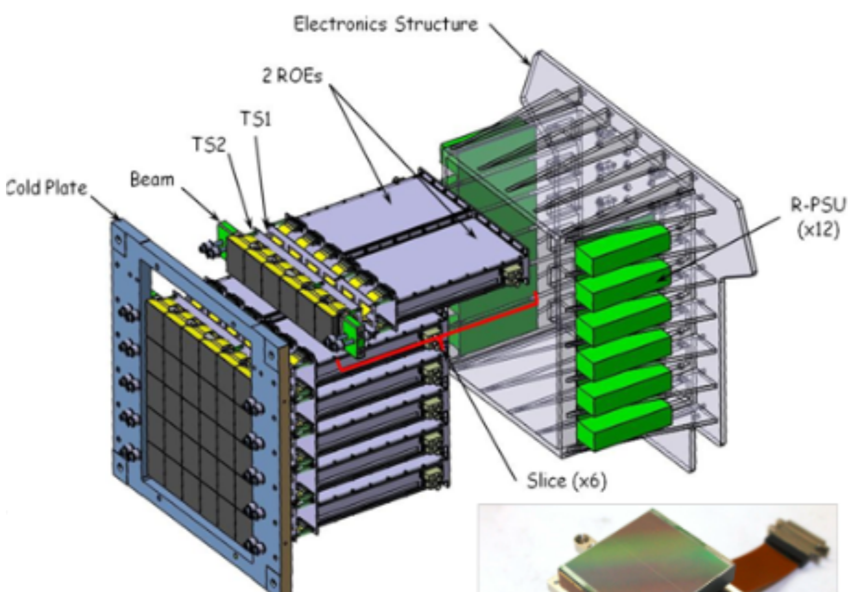


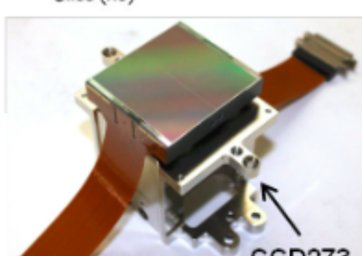
VIS and NISP

VIS

Courtesy: S. Pottinger, M. Cropper and the VIS team

- FoV: 0.54deg^2
- Mass : 133 kg
- Telemetry: < 520 Gbt/day
- 36 4kx4K E2V CCDs, 12 micron pixels
- 0.1 arcsec pixel on sky
- Limiting mag, wide survey AB : 24.5 (10 σ)
- **1 Filter**: Y(R+I+Y): band pass 550-900nm

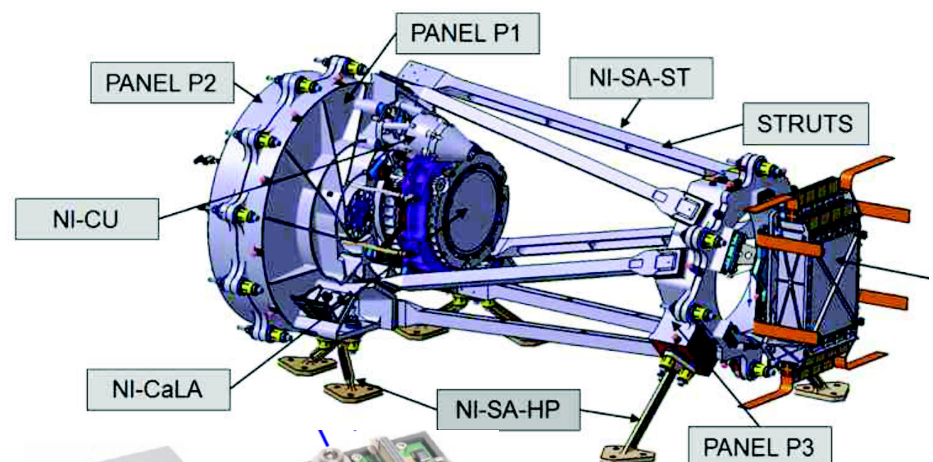




NISP

Courtesy: T. Maciaszek and the NISP team

- FoV: 0.55 deg^2
- Mass : 159 kg
- Telemetry: < 290 Gbt/day
- Size: 1m x 0.5 m x 0.5 m
- 16 2kx2K H2GR detectors
- 0.3 arcsec pixel on sky
- Limiting mag, wide survey AB : 24 (5 σ)
- **3 Filters**: Y, J, H
- **4 grisms**: 1B (920 – 1250) ,3R (1250 – 1850)



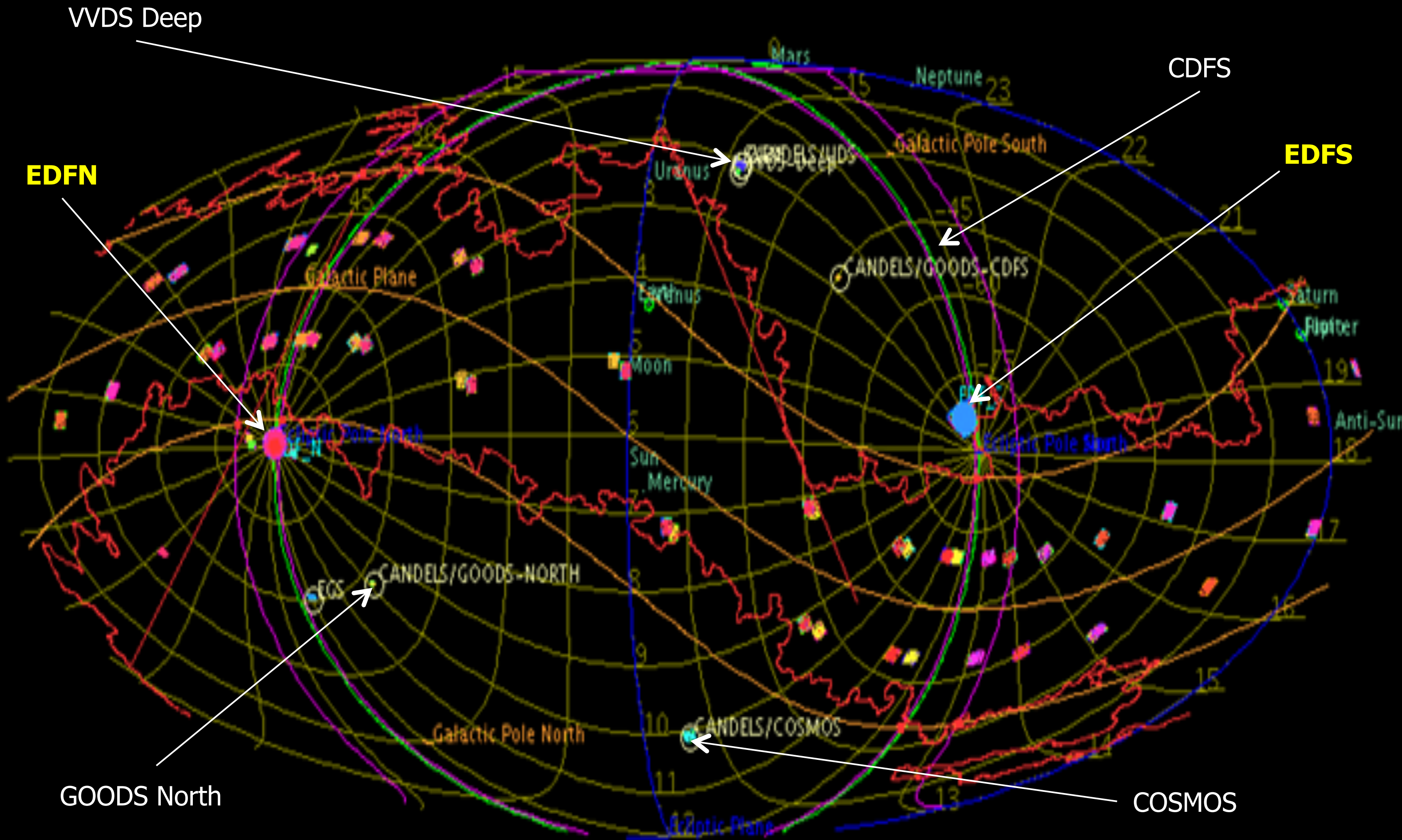
Euclid Legacy value

- **Euclid Wide:**
  - 15000 deg^2 outside the galactic and ecliptic planes
  - 12 billion sources (3-sigma)
  - 1.5 billion galaxies with
    - Very accurate morphometric information (WL)
    - Visible photometry: (u), g, r, i, z , (R+I+Z) AB=24.5, 10.0 σ +
    - NIR photometry : Y, J, H AB = 24.0, 5.0σ
    - Photometric redshifts with 0.05(1+z) accuracy
  - 35 million spectroscopic redshifts of emission line galaxies with
    - 0.001 acccuracy
    - Halpha galaxies within $0.7 < z < 1.85$
    - Flux line: $2\ 10^{-16}$ $erg.cm^{-2}.s^{-1}$; 3.5σ

Euclid Legacy value

- **Euclid Deep:**
  - 2x20 deg^2 at ecliptic poles
  - 10 million sources (3-sigma)
  - 1.5 million galaxies with
    - Very accurate morphometric information (WL)
    - Visible photometry: (u), g, r, i, z , (R+I+Z) AB=26.5, 10.0 σ +
    - NIR photometry : Y, J, H AB = 26.0, 5.0σ
    - Photometric redshifts with 0.05(1+z) accuracy
  - 150000 spectroscopic redshifts of emission line galaxies with
    - 0.001 acccuracy
    - Halpha galaxies within $0.7 < z < 1.85$
    - Flux line: 5 10^{-17} $erg.cm^{-2}.s^{-1}$; 3.5σ

Legacy value of Euclid calibration fields



- Calibration sequence over 6 years (ecliptic coordinates, Mollweide projection)→All calibration fields are shown, including HST targets and the EDFS and EDFN near the ecliptic poles. The ecliptic is shown as a vertical line, jagged lines show background level contour E(B-V)=0.08

Euclid Post-Planck Forecast for the Primary Program

Ref: Euclid RB arXiv: 1110.3193	Modified Gravity	Dark Matter	Initial Conditions	Dark Energy		
Parameter	γ	m_{ν} /eV	f_{NL}	w_p	w_a	FoM $= 1/(\Delta w_0 \times \Delta w_a)$
Euclid primary (WL+GC)	0.010	0.027	5.5	0.015	0.150	430
EuclidAll (clusters,ISW)	**0.009**	**0.020**	**2.0**	**0.013**	**0.048**	**1540**
Euclid+Planck	0.007	0.019	2.0	0.007	0.035	**6000**
Current (2009)	**0.200**	**0.580**	**100**	**0.100**	**1.500**	**~10**
Improvement Factor	**30**	**30**	**50**	**>10**	**>40**	**>400**

DE equation of state: $P/\rho = w$, and $w(a) = w_p + w_a(a_p - a)$

From Euclid data alone, get FoM=$1/(\Delta w_a \times \Delta w_p)$ > 400→ ~1% precision on w's.

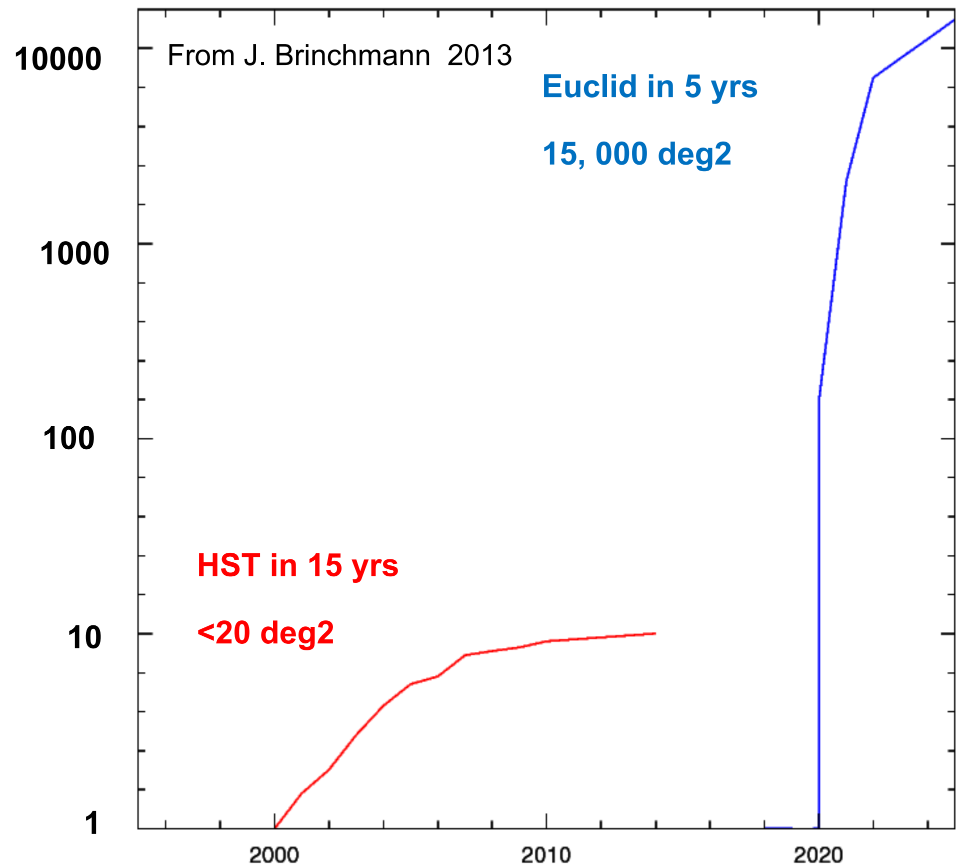
Growth rate of structure formation: $f \sim \Omega^{\gamma}$; .

Notice neutrino constraints -> minimal mass possible ~ 0.05 eV

Euclid:

contributing to the next generation wide field VIS/NIR surveys for the whole scientific community

- Very large samples
  - → Diversity of populations
  - → Distribution functions
  - → ~50,000 clusters of galaxies
- Huge volumes and numbers
  - → Rare sources, probing the extremes
- Exquisite imaging of galaxies
  - → Morphologies, mergers, galaxy-scale lenses
  - → Observations of 10^6 dwarf galaxies
- Strong and Weak Lensing
  - → Galaxy evolution as function of halo properties
  - → Galaxy alignement
  - → 5000 clusters with giant arcs
- NIR Spectroscopy
  - → Metals, star formation@ z>1
  - → Cool stars
  - → Very high-z QSOs



Legacy Science Working Groups

- Extra-solar planets
- Milky way and Resolved Stellar populations
- Local Universe
- Galaxies and AGN evolution
- Primeval Universe
- Clusters of galaxies
- Strong lensing
- CMB Cross-correlations
- Cosmological Therory
- Cosmological simulations
- Supernovae and transients

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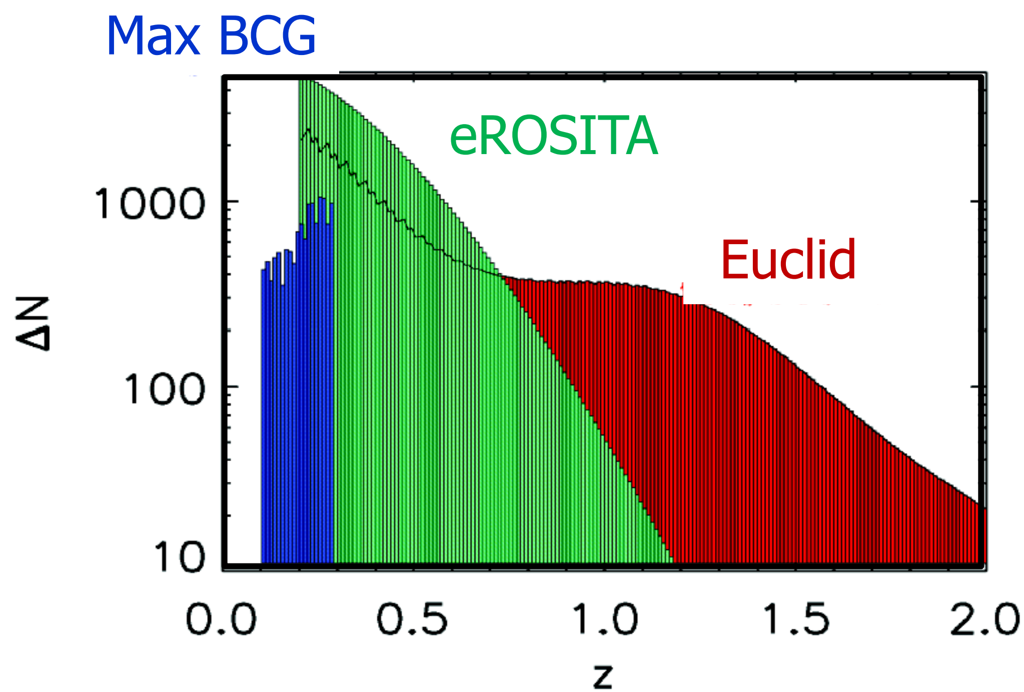
Clusters of galaxies with Euclid

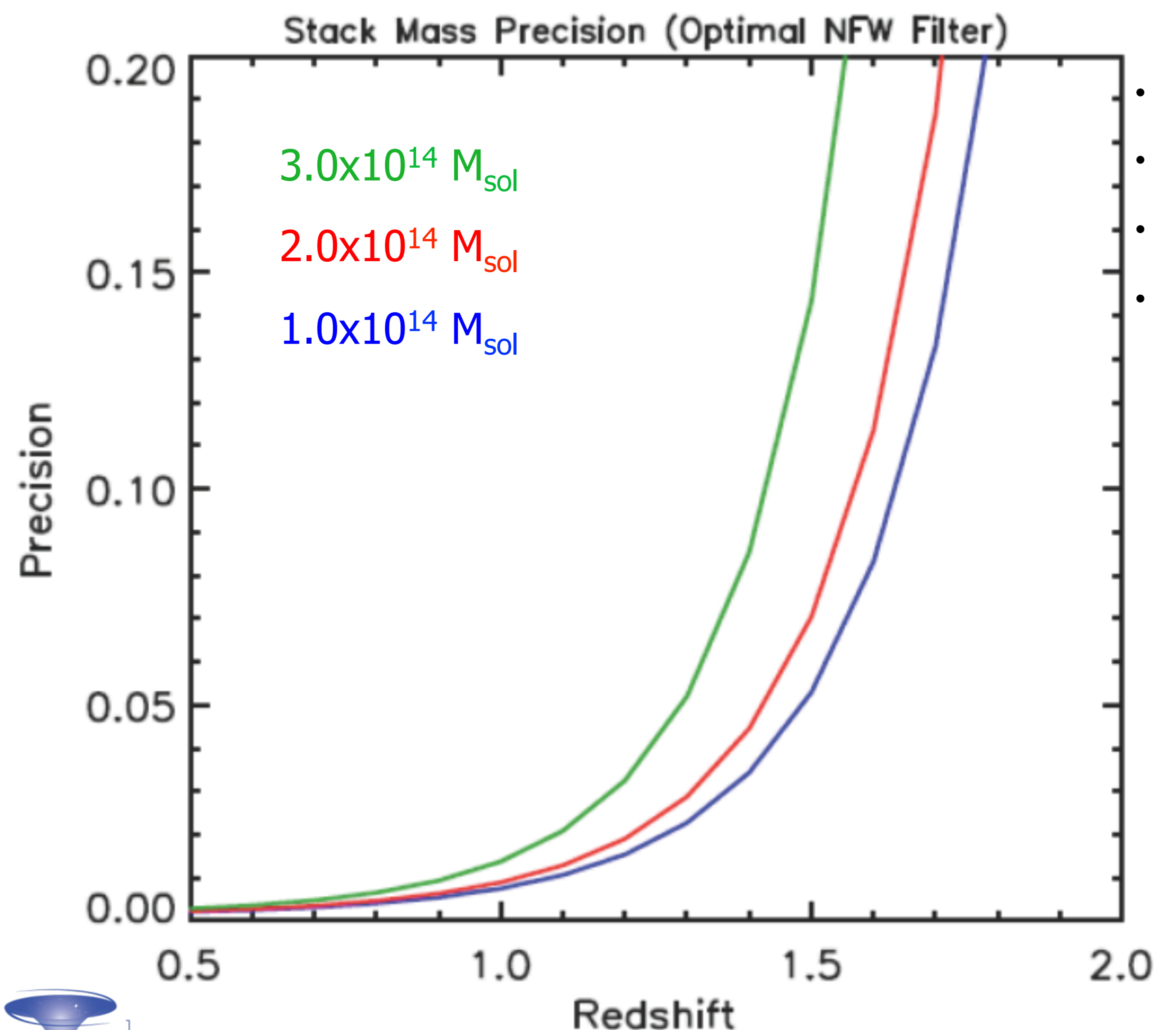
- Probe of peaks in density distribution
- Nb density of high mass, high redshift clusters very sensitive to
  - primordial non-Gaussianity and
  - deviations from standard DE models
- Euclid data will get for free:
  - Λ-CDM: all clusters with M>2 10^{14} Msol detected at 3-σ up to z=2
    - → 60,000 clusters with 0.2<z<2 ,
    - → 1.8 10^4 at z>1.
  - ~ 5000 giant gravitational arcs
    - → very accurate masses for the whole sample of clusters (WL)
    - → dark matter density profiles on scales >100 kpc

Synergy with Planck and eROSITA



Scaling relations with Euclid Clusters

Expected precision on the mean mass of clusters with gravitational shear in bin of $\Delta\log(M200)=0.2$ and $\Delta z=0.1$



- Survey of 15,000 deg^2
- Λ-CDM Planck cosmology
- Tinker mass function
- Shape noise of 0.3

Euclid has the potential to calibrate the mean mass, and hence the scaling relations, to 1% out to z=1.0 and to 10% out to z=1.6

Sartoris et al 2015

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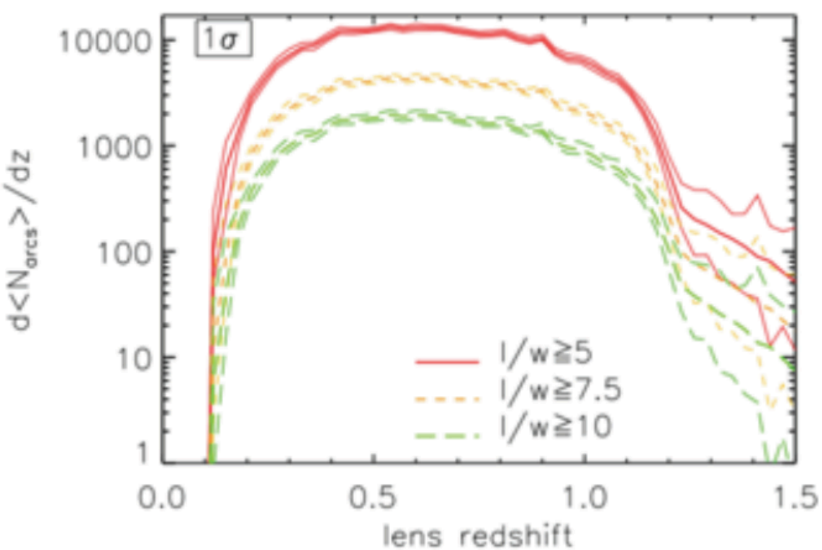
Strong lenses seen with Euclid:

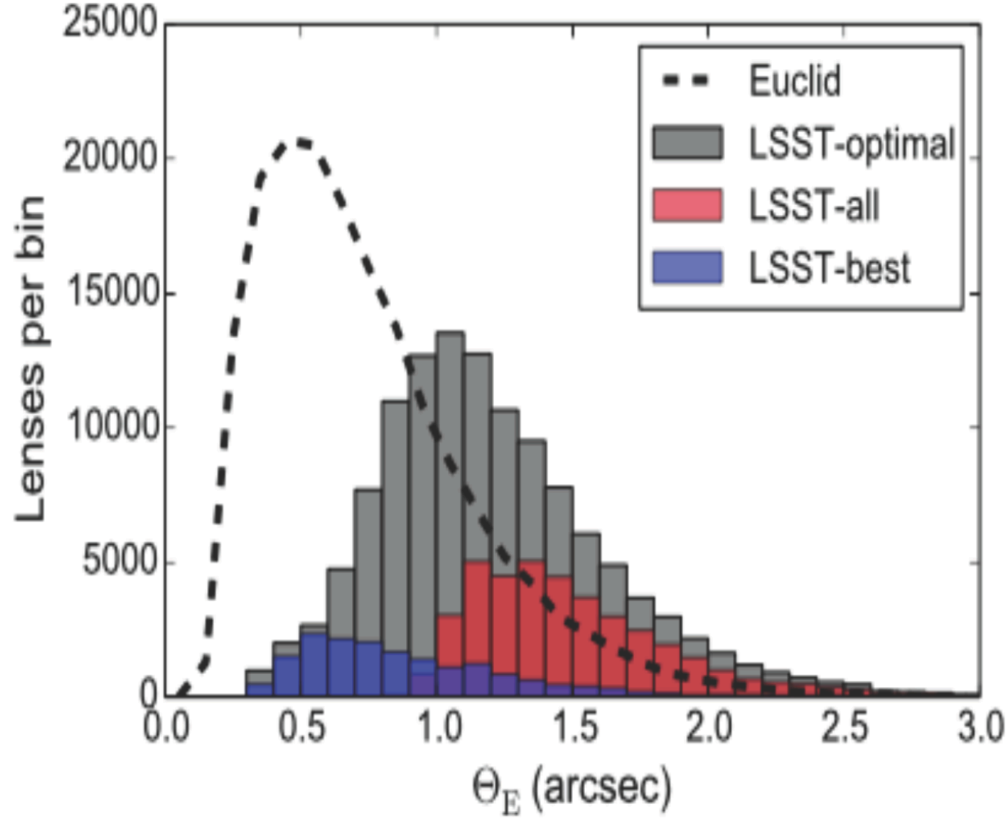
- Galaxy-galaxy lensing
- Galaxy-QSO lensing
- Gravitational arcs
- Compound lenses
- Multiple images in clusters
- Exotic lenses

Strong Lensing



Giant arcs in clusters (Boldrin et al 2015)

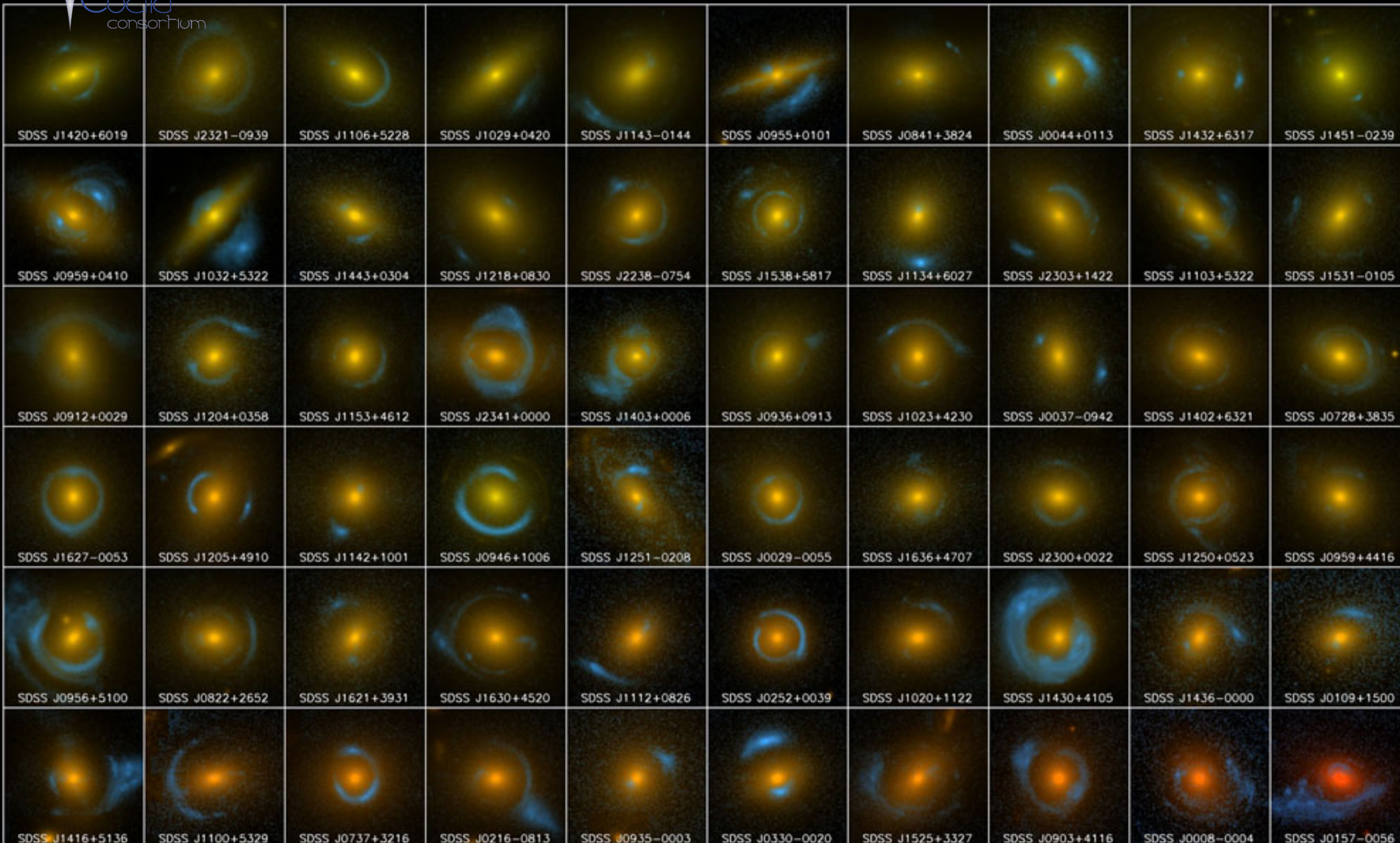
- 1300 arcs wit L/w >10
- 8000 arcs with L/w > 5



Galaxy-galaxy lensing (Collett 2015)

- 140,000 lenses in the wide survey
- 650 double surce plane lenses

SLACS (~2010 - HST)



SLACS: The Sloan Lens ACS Survey www.SLACS.org

Bolton (U. Hawai'i IfA), L. Koopmans (Kapteyn), T. Treu (UCSB), R. Gavazzi (IAP Paris), L. Moustakas (JPL/Caltech), S. Burles (MIT)

Image credit: A. Bolton, for the SLACS team and NASA/ESA


SLACS
Euclid VIS Legacy : after 2 months
(66 months planned)

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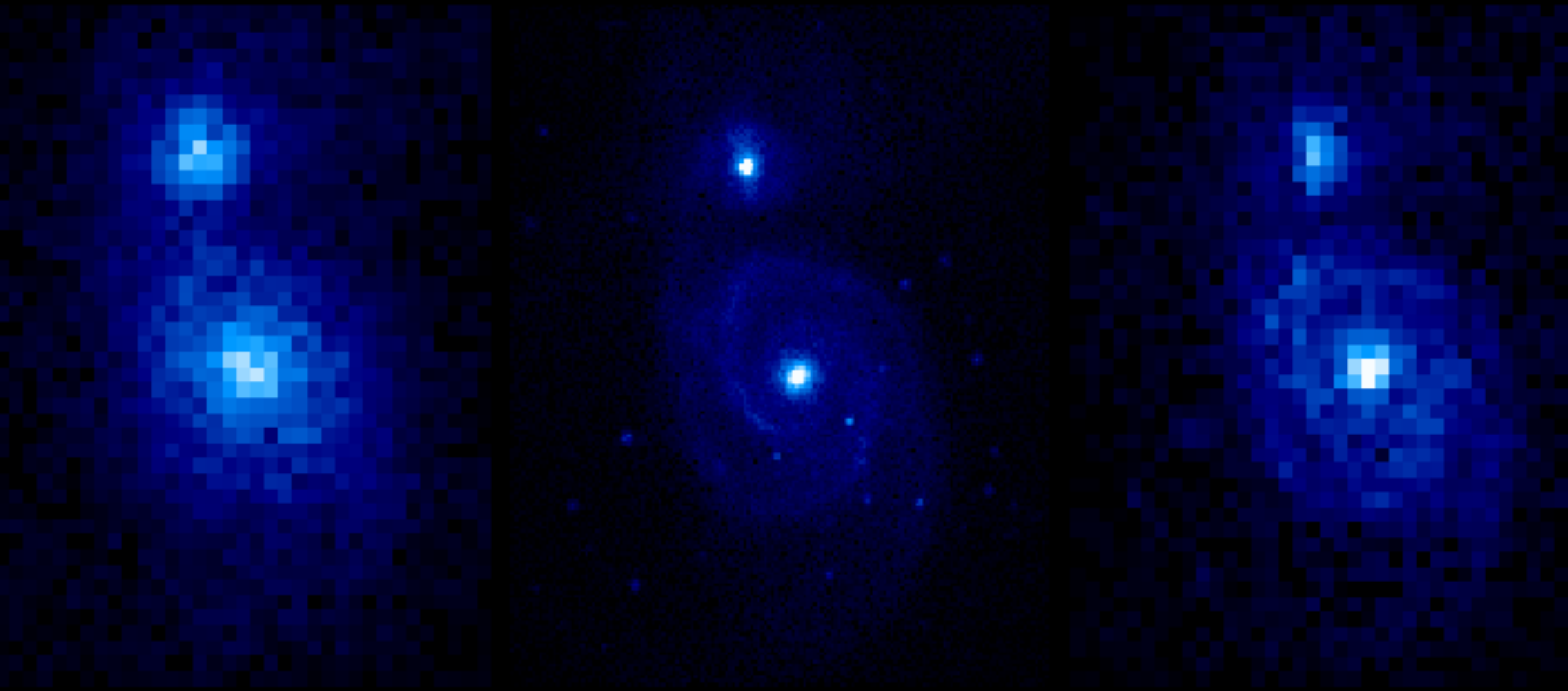
VIS: Simulation of M51

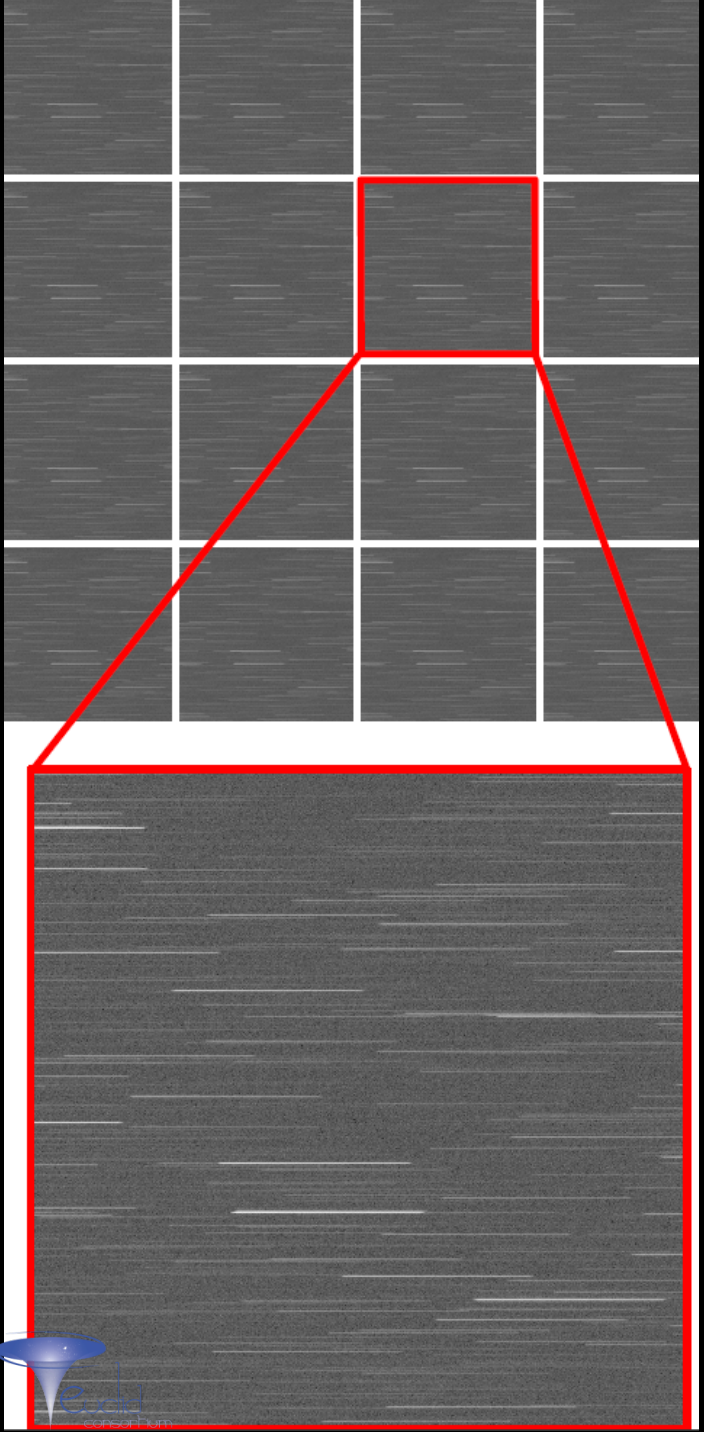
From J. Brinchmann



2.4m SDSS-like @ z=0.1 | Euclid @ z=0.1 | Euclid @ z=0.7

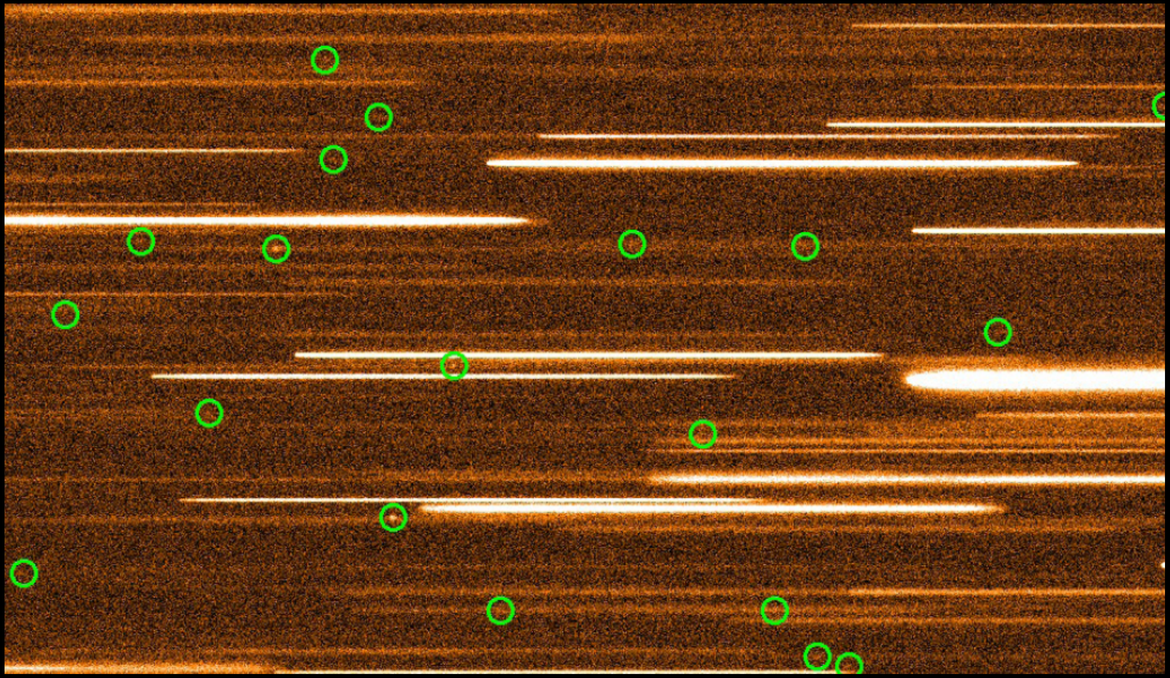
Euclid will get the resolution of SDSS but at z=1 instead of z=0.05.

Euclid will be 3 magnitudes deeper → Euclid Legacy = Super-Sloan Survey



NISP-spectroscopy for Euclid (2015)

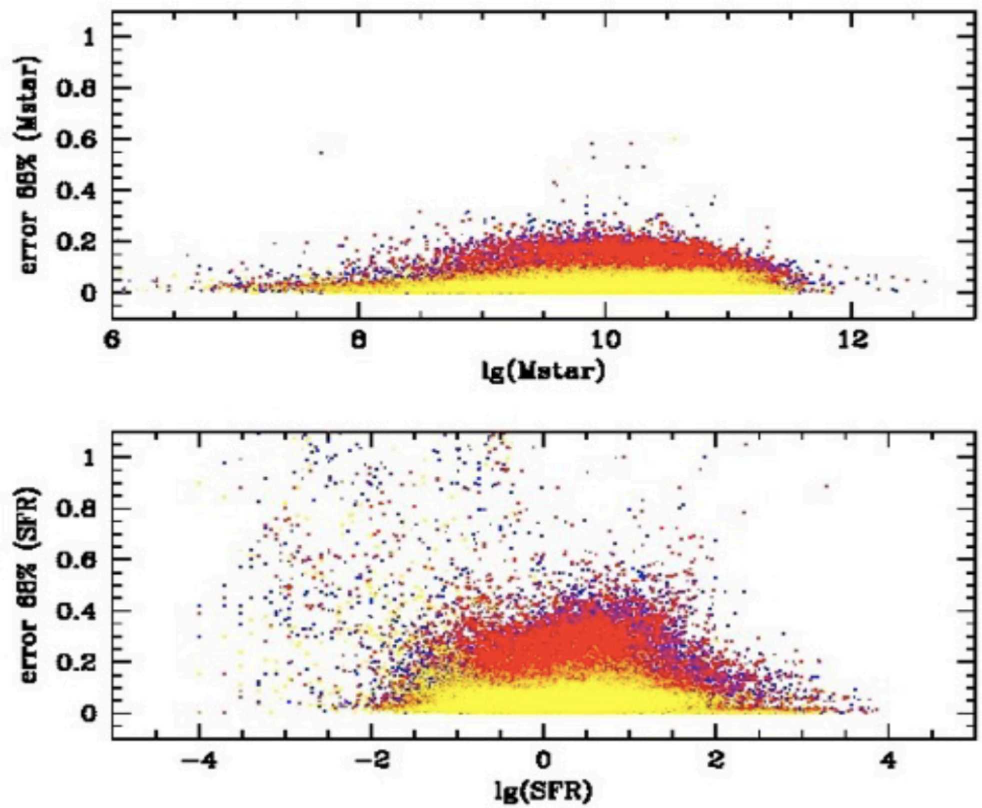
From P. Franzetti, B. Garilli, A. Ealet, N. Fourmanoit & J. zoubian



35 million spectra with at least 3 exposures taken with 3 different orientations and a total exposure time of 4000 sec.

Galaxy evolution with Euclid: physical parameters

From Pozzetti & Bolzonella



Accuracy on physical parameters from SED fits on Euclid AGNs, emission lines galaxies

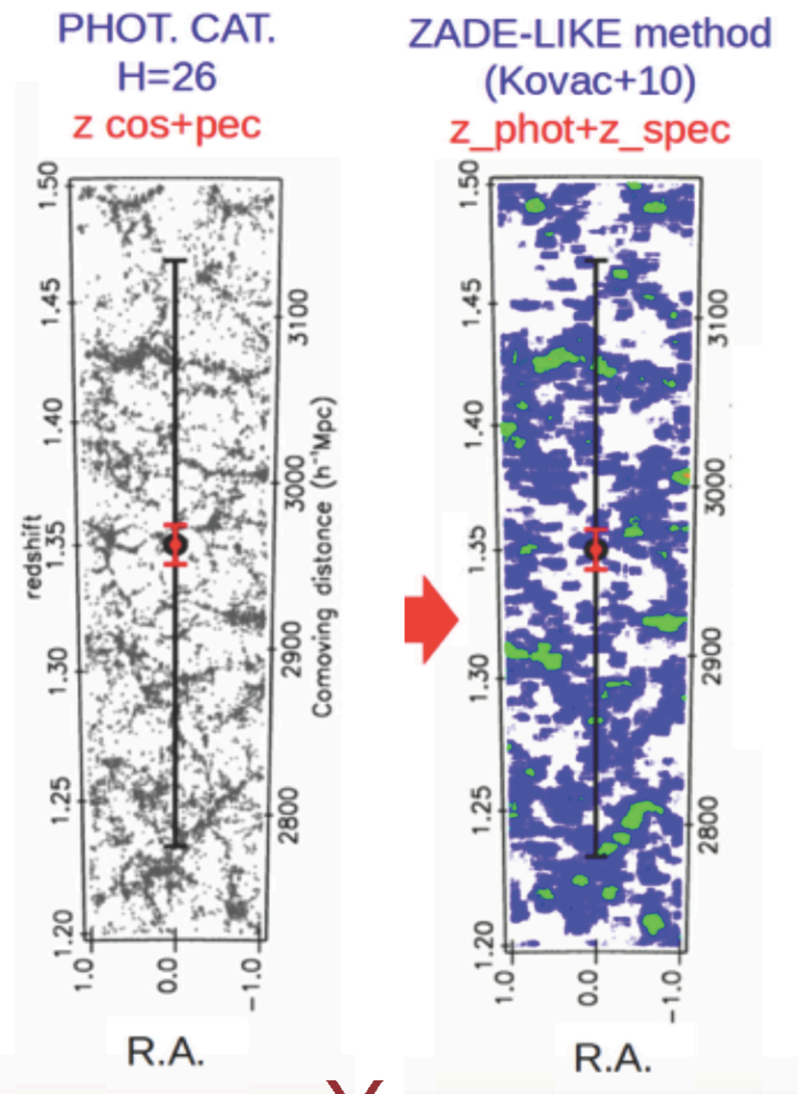
σ_{Mass} worse by 0.1-0.2 dex and

σ_{SFR} worse by 0.3 dex

relative to COSMOS

Galaxy evolution with Euclid: local environments

Will Euclid data have enough spatial resolutions to characterise local environments?

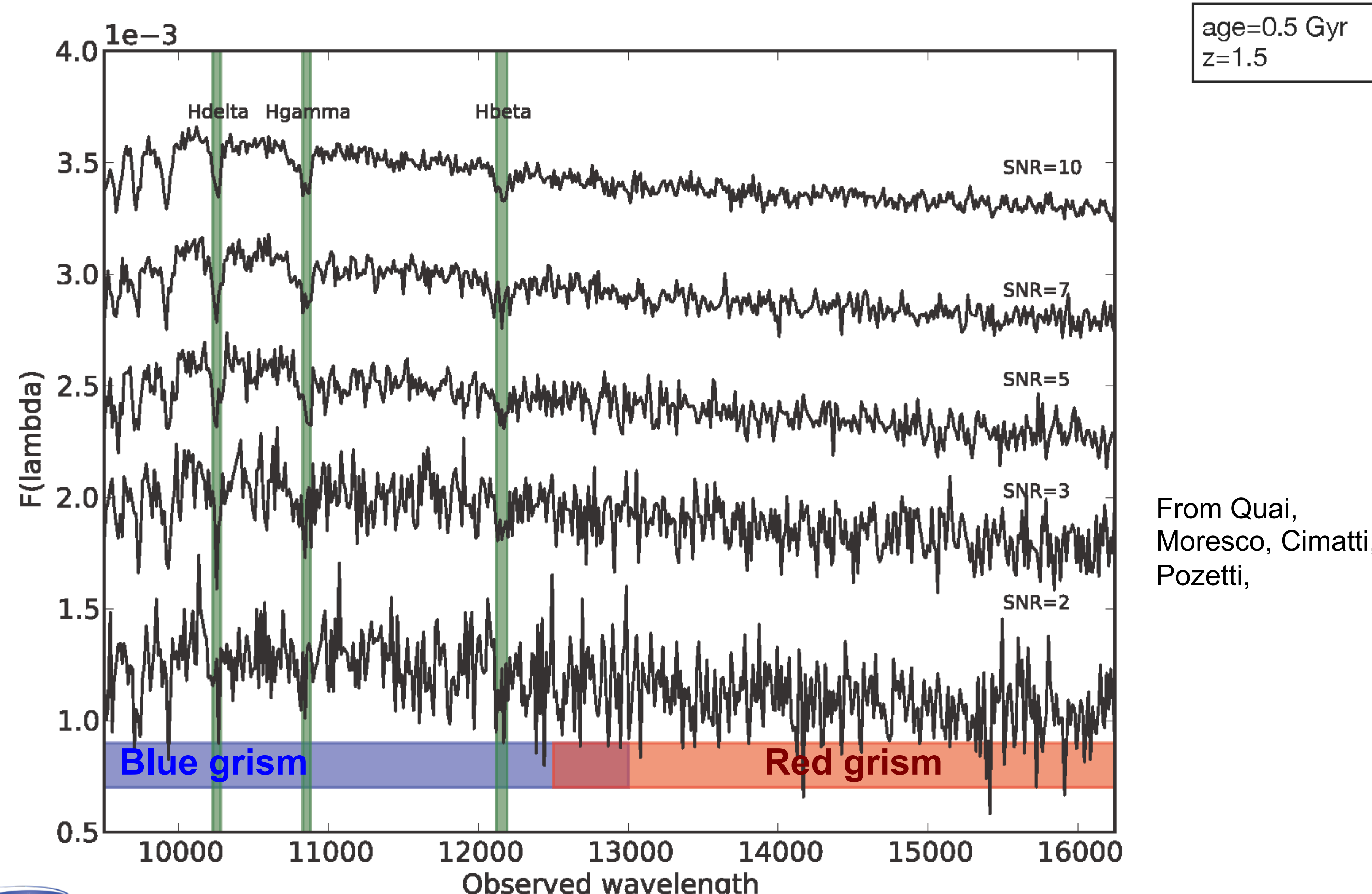


From Cucciati

Yes

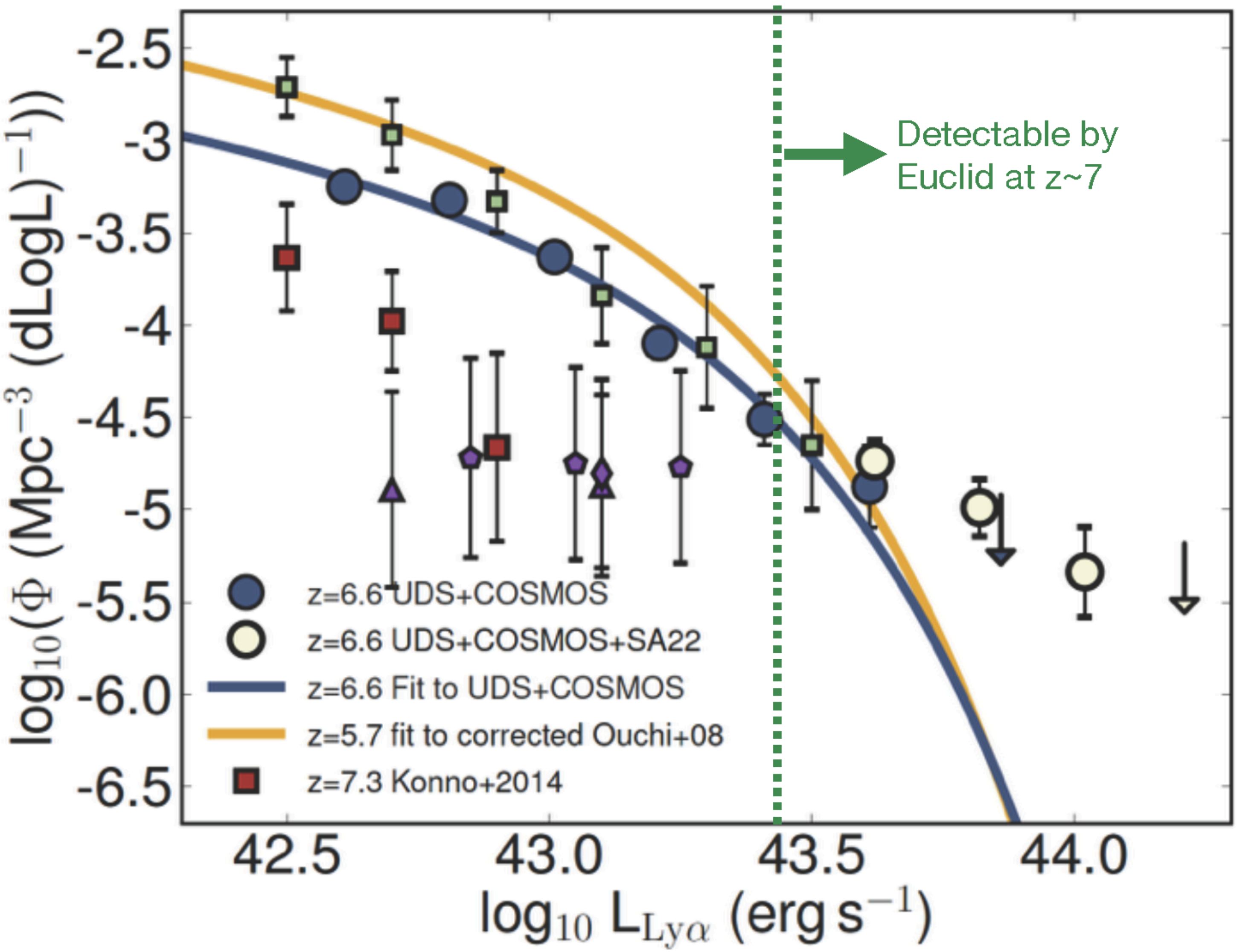
Communit

Measuring absorption lines on Euclid spectra



From Quai, Moresco, Cimatti, Pozetti,

Prospect for detecting high-z Ly-a emitters



From Matthee et al (2015)

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Microlensing survey?

3 fields observed every 17mn in H, every 12 hours in VIS, J and Y

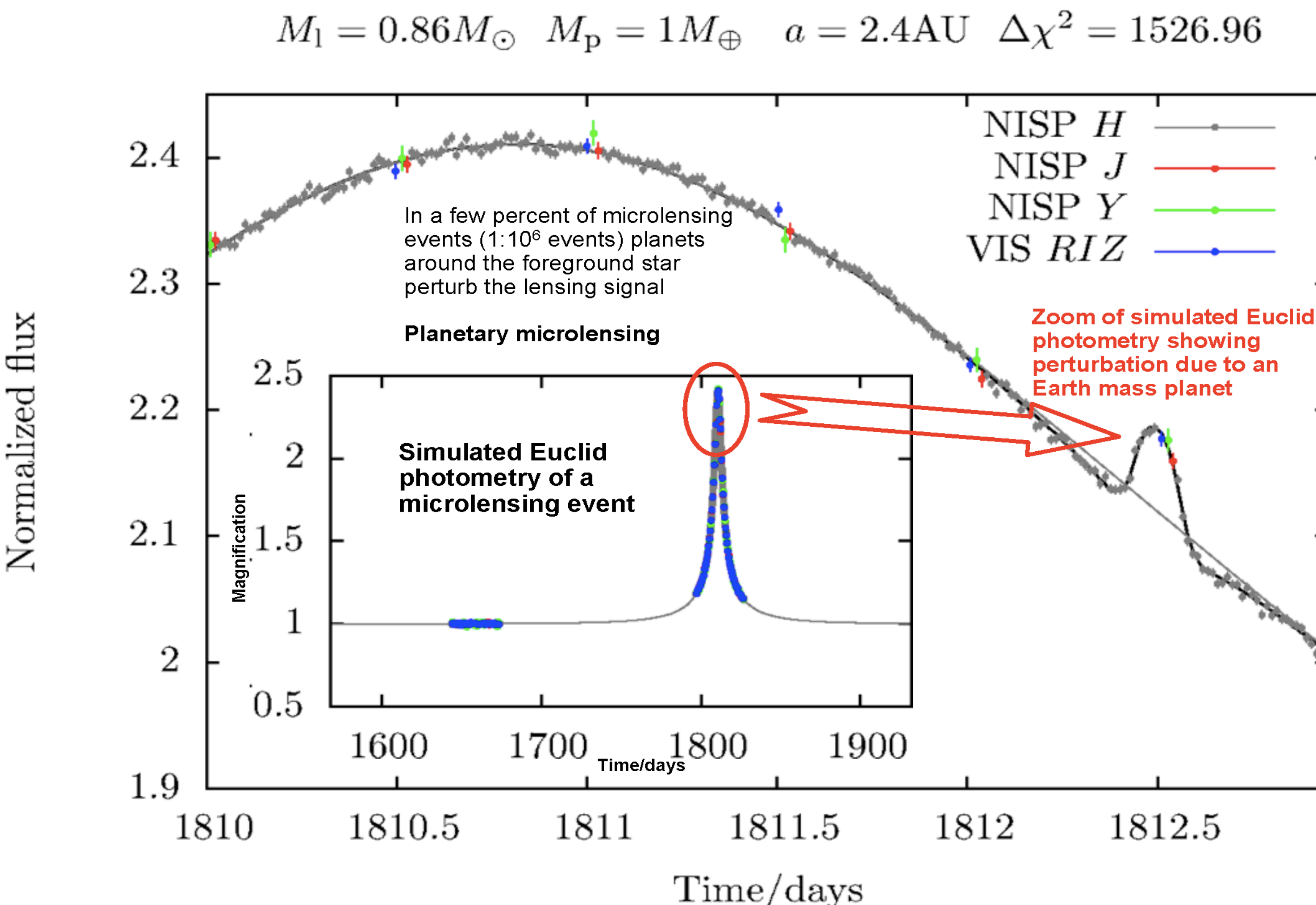
- Mini-survey during commissioning (24h),
- then 4x1 months survey
- Measuring cold Earth abundance and mass function
  - 35 planets/months (5 Earth/month, 15 Neptune/month)
- Getting constraints on free-floating planets
  - 15 free floating planets/month

Euclid will complement the parameter space probed by RV and Kepler

- Measuring the cold planet mass function below 1 Earth mass

Possibility of simultaneous Euclid-WFIRST in the extended mission 2026+ : parallax between Euclid and WFIRST to measure masses of Earth mass free floaters)? → still valid witht the new WFIRST orbit in L2?

Microlensing survey?



From Beaulieu and Penny et al 2013

WFIRST and Euclid are Complementary

- Understanding dark energy will require tight control of systematics and multiple cross checks
- **WFIRST-AFTA**
  - Is deep, infrared over 2000 square degrees
  - Multiple shape measurements in 2-3 well–sampled bands
  - Higher resolution and source density (2.5 times as many as Euclid)
  - High quality survey of >2000 SN using a dedicated IFU
  - Redshift survey for galaxy clustering extends to z=3
- **Euclid**
  - Measures shapes in single optical band but with CCD detectors very well known for WL. Different systematics than WFIRST-AFTA, lower redundancy and internal cross-checks.
  - Much wider (15,000 deg^2) but shallower
  - No SN
  - Lower redshift range for galaxy clustering
  - Launch in 2020, survey completed by 2026: 2500 deg^2 public in 2023, 7500 deg^2 in 2025, final 2027.
- **Euclid-WFIRST data processing synergy:** lessons learned from Euclid (H2RG detectors, Grisms), tens of scientists and engineers involved in both surveys

The best constraints on DE and Legacy in the 2020s will come from a combination of Euclid, WFIRST and ground-based (LSST, Subaru) data