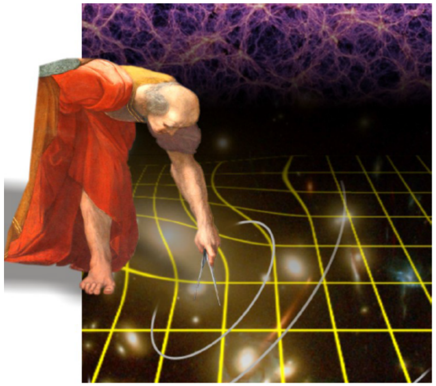
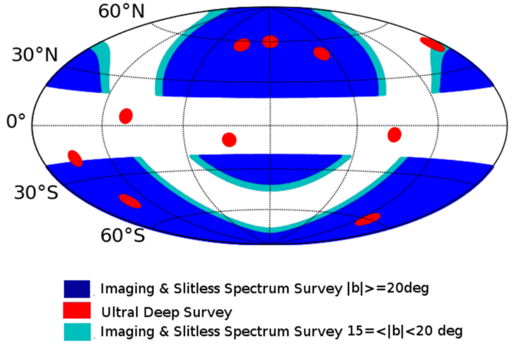
Summary of the presentations Cosmology with ESA Euclid* and CSS-OS**

Charling Tao
CPPM/IN2P3/CNRS
and
THCA, Tsinghua University



- Euclid/CSSOS Project office
- Euclid Transient SWG co-lead
- Void BAO
- Probe combinations



- Cf Presentations of Euclid and CSSOS by Tim SCHRABBACK* and ZHAN Hu**

Euclid/CSSOS: Cosmology Objectives

- Understanding the origins of the Universe accelerating expansion
- Derive properties and nature of Dark Energy(DE), test gravity (MG)
- Distinguish DE,MG, DM (Dark Matter) effects

- *Decisively* by:
  - Using at least 2 independent but complementary probes
  - Tracking their observational features on the
    - Geometry of the Universe with 2 main probes:

      Weak Lensing (WL), Galactic Clustering (GC)
    - Cosmic history of structure formation: WL, redshift space distortion, Clusters of galaxies

  - **Precise Control of systematics**

Systematics and controls of systematics

- **Photo z : dispersions and catastrophic errors***
  - Jean-Paul KNEIB, LI Ran
  - Angus WRIGHT first combined CSSOS-Euclid results for the « White book »
  - Complementary data from ground for Euclid (/CSSOS) Martin KILBINGER
  - message from Henry McCRACKEN
- **PSF** with galaxy images LI Guo Liang
- **CCD effects** on shear measurements Reiko NAKAJIMA
- Experience with **VOICE shear measurements** FU Liping
- **Shear Measurements in Fourier Space** ZHANG Jun

WL data analyses pipeline Samuel FARRENS

Full sky WL simulation WEI Chengliang/KANG Xi

Message from Henry Mc Cracken
Dec 18, 2018

- we are developing the VIS processing function at IAP for Euclid

  and in addition to that I have started
- an independent data centre dedicated to processing complimentary data in the Euclid deep fields (calet.org).

- I am sure there would be some contribution we could make!

Catastrophic Photo-z Errors and the DE Parameter Estimates with Cosmic Shear

- Sun, Lei; Fan, Zu-Hui; Tao, Charling; Kneib, Jean-Paul; Jouvel, Stéphanie; Tilquin, André. Ap J 699, Issue 2, pp. 958-967 (2009).

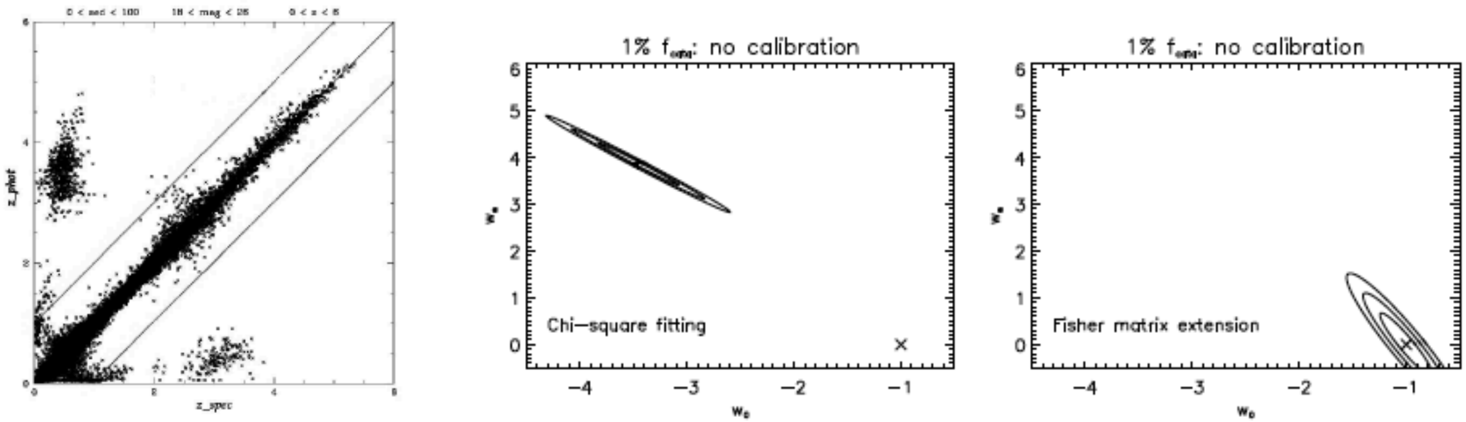
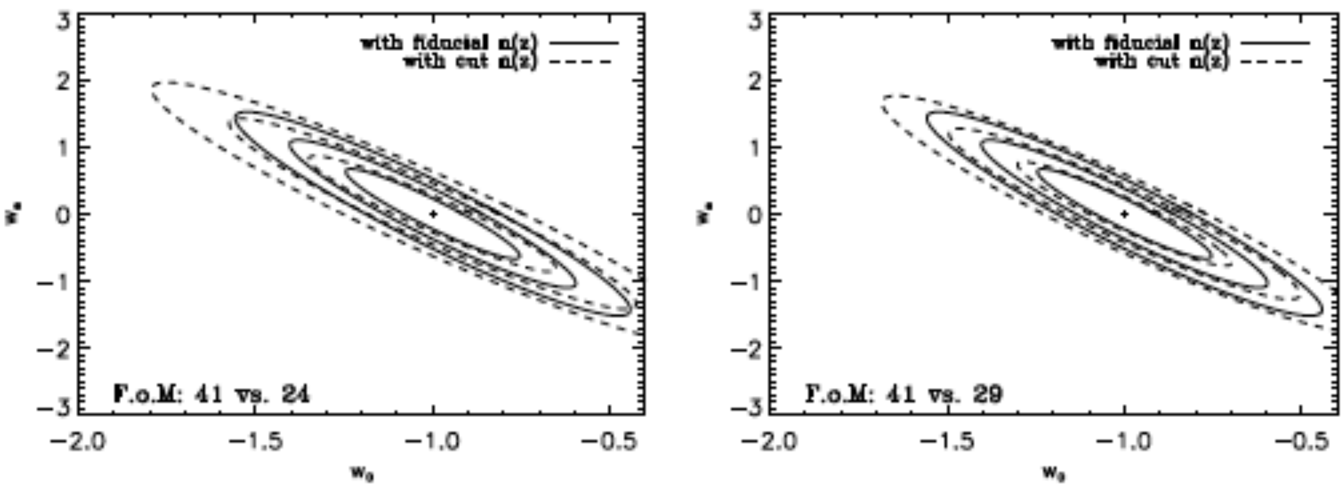


Fig. 1.—
cut of 26
inside w



Weak Lensing Science

- **Cf Summaries** for CSS-OS and Euclid by ZHAN Hu and Tim SCHRABBACK
- **Magnification** Brice MENARD
- **Constraints on f(R) with peak statistics** FAN Zuhui
- **Stellar-to-halo mass ratio with DECam** SHAN HuanYuan

Vulcani et al. 2014

Effective radius vs wavelength

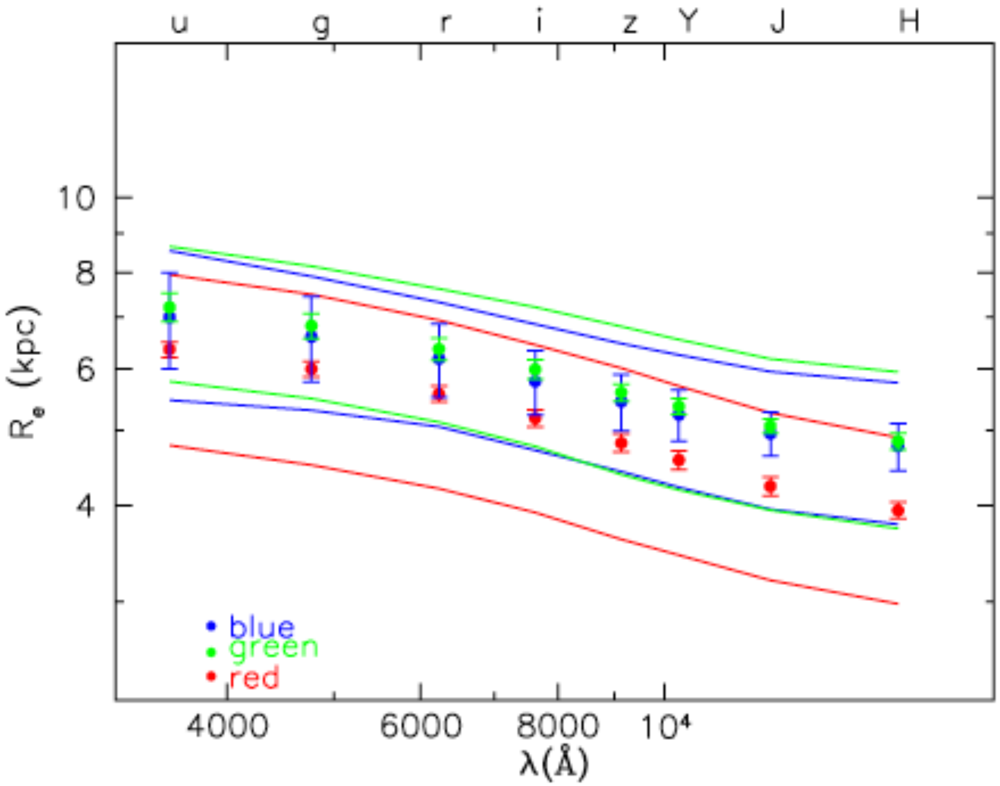
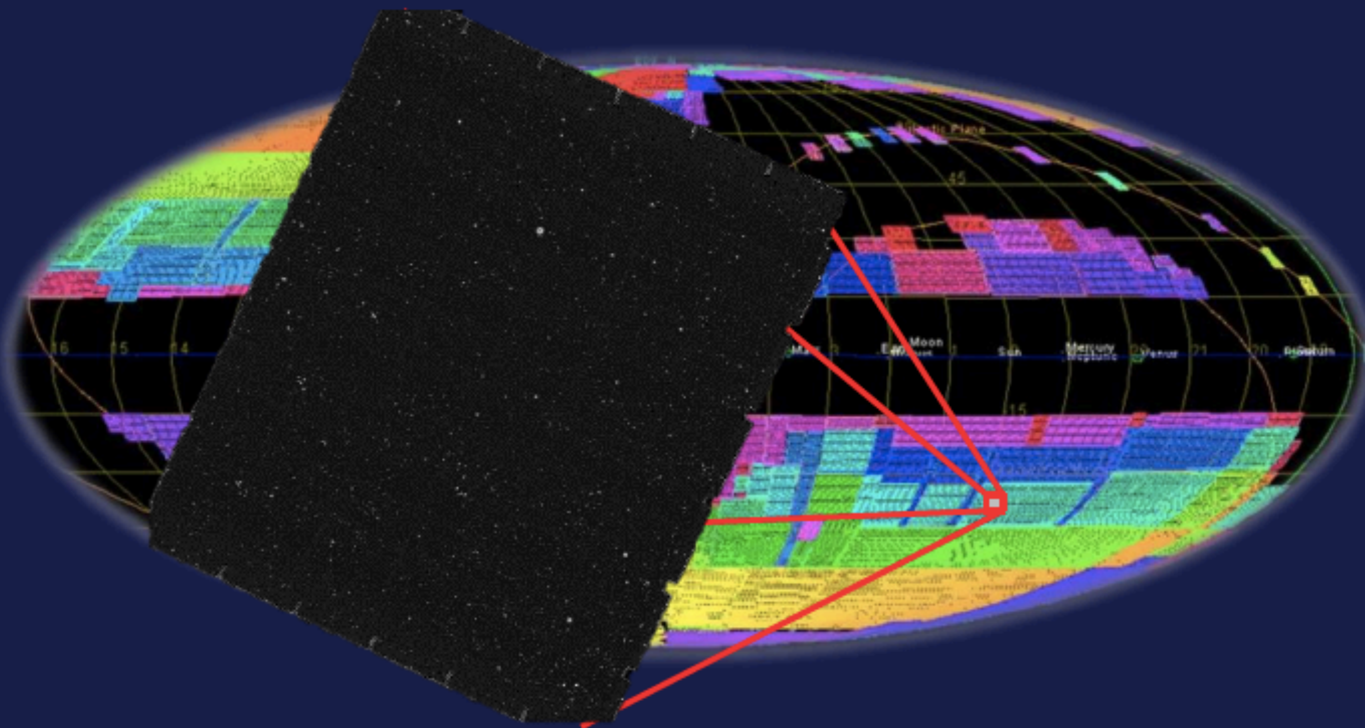


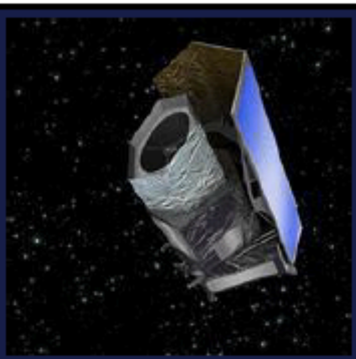
Figure 12. Median effective radius as a function of wavelength for our *red*, *green* and *blue* galaxy samples. Error bars represent the uncertainty on the median. Solid lines indicate the 16th- and 84th-percentiles of the distribution. The effective radius clearly depends on wavelength. *Blue* and *green* galaxies show very similar behaviour, while *red* galaxies have systematically smaller effective radii and a slightly steeper dependence on wavelength.

Euclid Survey



Euclid

- Survey 15000 deg²
- Visible & Infrared
- Diameter 1.2 m
- Field 0.5 deg²



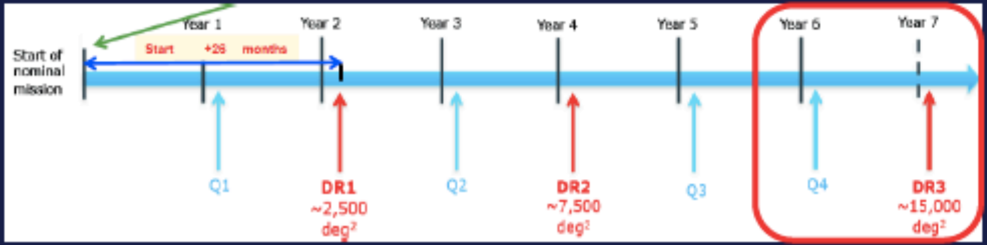
15 000 deg² covered in 5 years

Survey build of 30 000 fields observation 0,5 deg² repeated on the sky (+10 000 fields of calibrations)

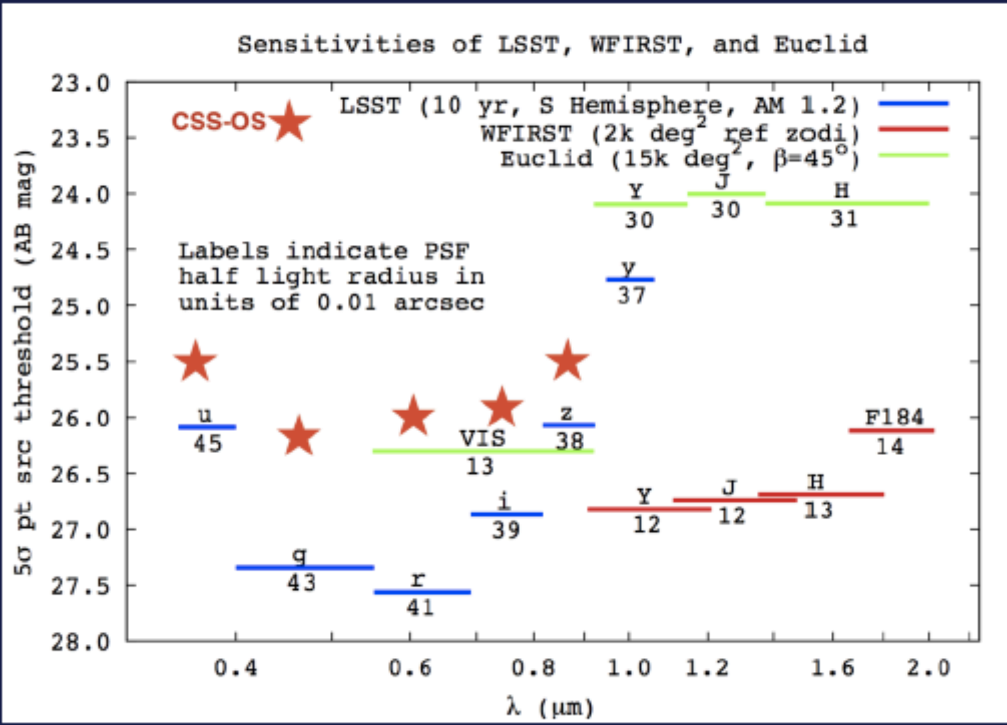
160 000 frames in Visible / Y / J / H bands and Spectroscopy [1200-1850] nm

Euclid and CSS-OS will share strong synergy in the 2025 / 2030 timescale:

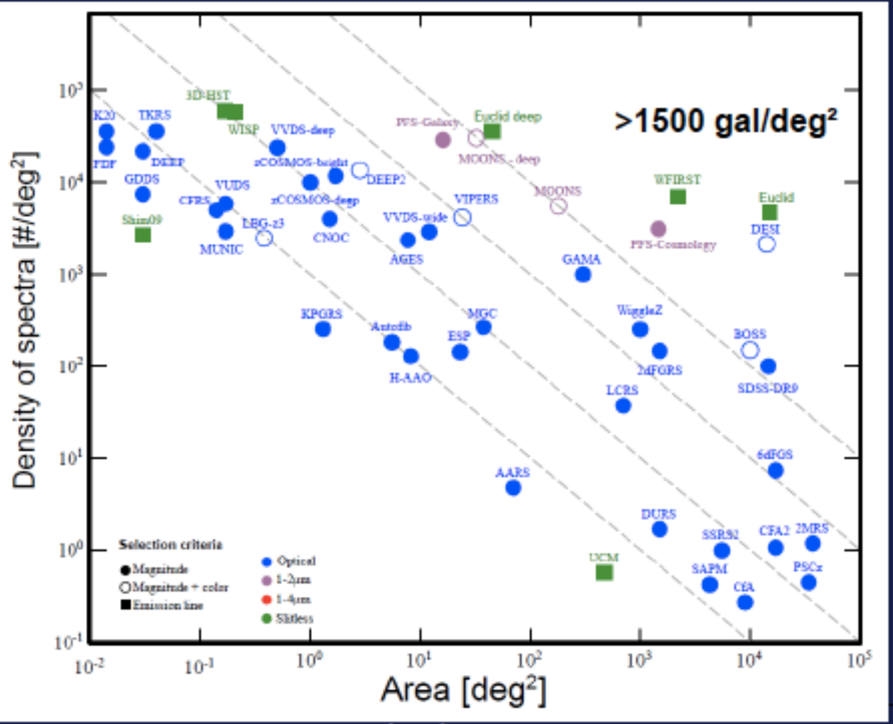
- Space Quality data over the best sky for cosmology
- Coverage of multi-wavelength data from UV to Near InfraRed
- Imaging and Spectroscopy data



Imaging



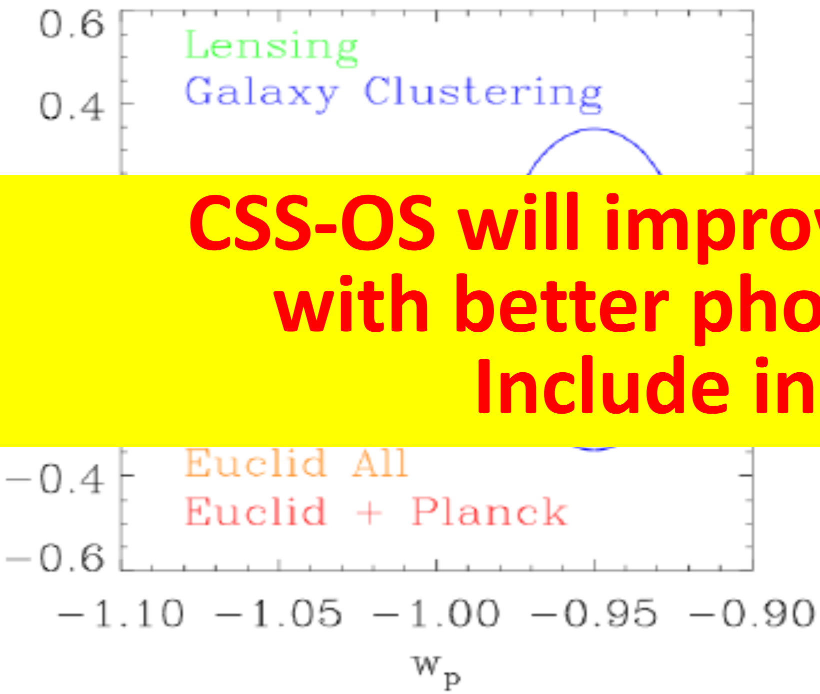
Spectroscopy



EUCLID

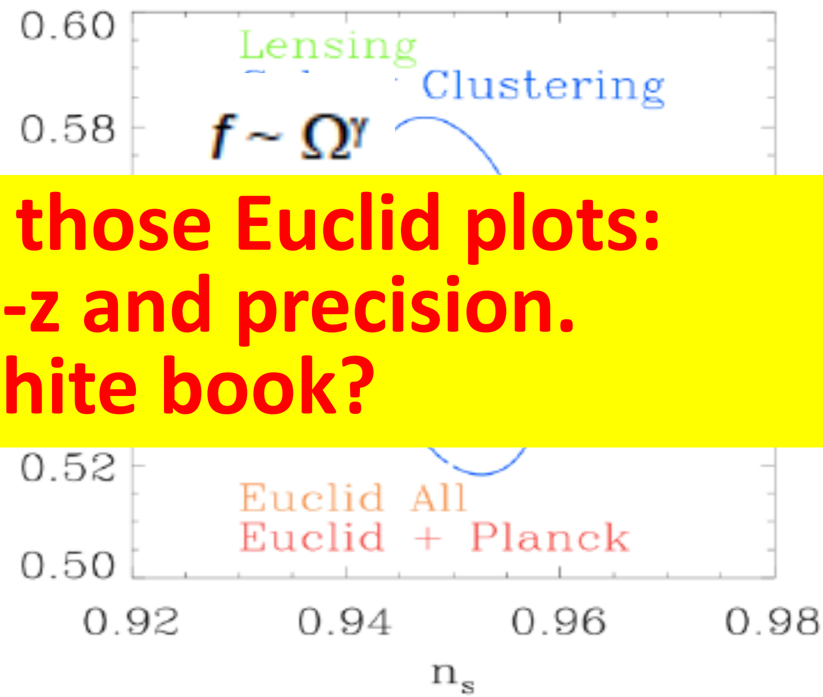
- DE equation of state:

$P/\rho = w$ and $w(a) = w_p + w_a(a_p - a)$



DE constraints from Euclid: 68% confidence contours in the (w_p, w_a).

- Growth rate of structure formation controlled by gravity:



Constraints on the γ and n_s. Errors marginalised over all other parameters.

CSS-OS will improve those Euclid plots: with better photo-z and precision. Include in white book?

Ref: Euclid RB arXiv:1110.3193

What other cosmology topics to include in « White Book »?

Beyond ISSI Proposal

Cosmology Highlights 2018

-DE or Cosmological constant ?

- **Planck 2018** : stable
- **SDSS BAO** (Alam et al. 2017), **RSD**
- **SN Pantheon (**Scolnic et al. 2018)
- **DES, KIDS, HSC** (Hikage et al. 2018)

- **H_0 tension** becomes **r_s tension**

- Is there DM? What DM?

- No need for DM in spheroidal dwarves: Hammer et al 2018
- Galaxy without DM

van Dokkum et al 2018

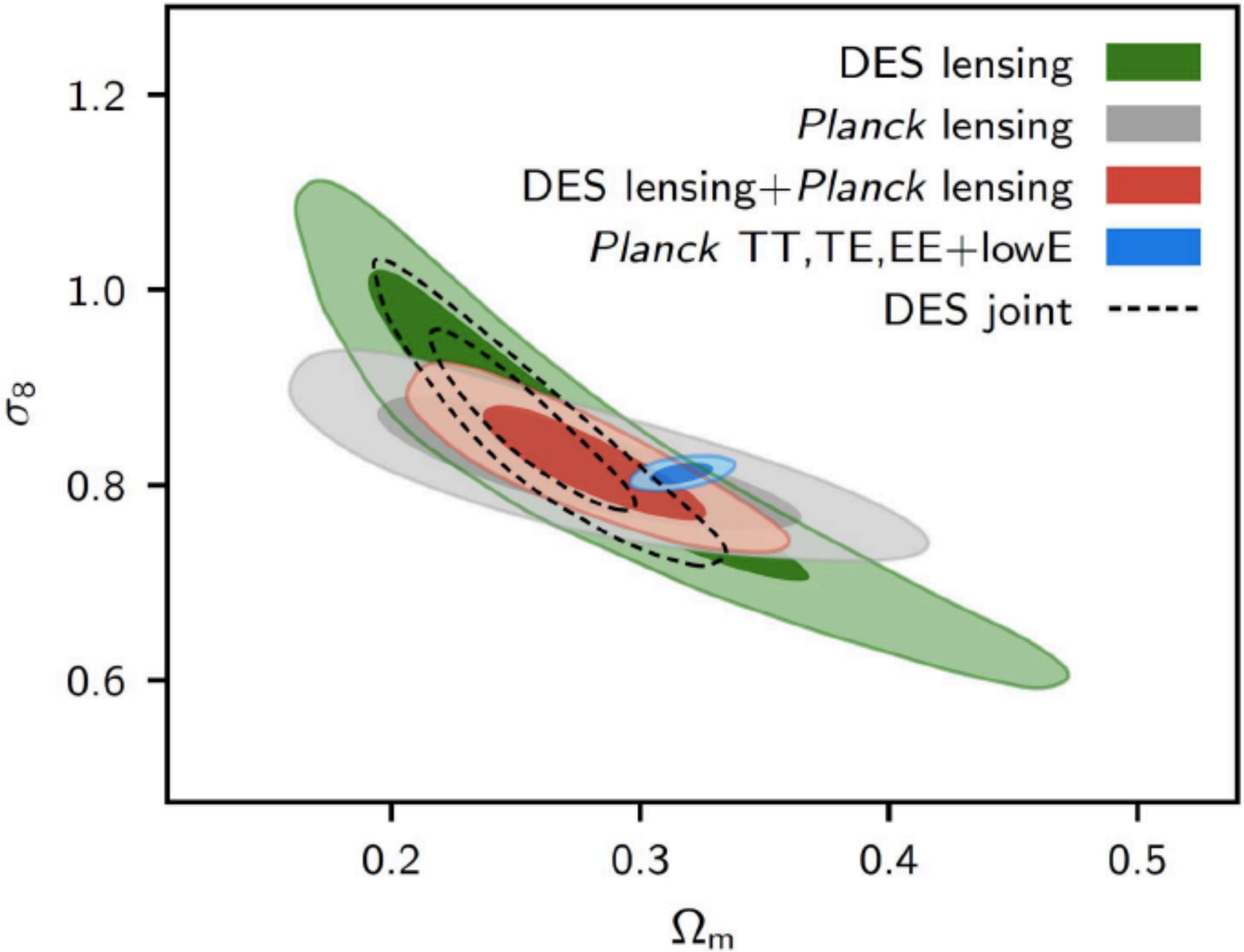
➔ Argument for DM

- SL can distinguish between WDM and CDM
- Caveat: Non-linear regions are regions of strong baryonic effects!

Planck 2018

VI. Cosmological parameters   March 2018

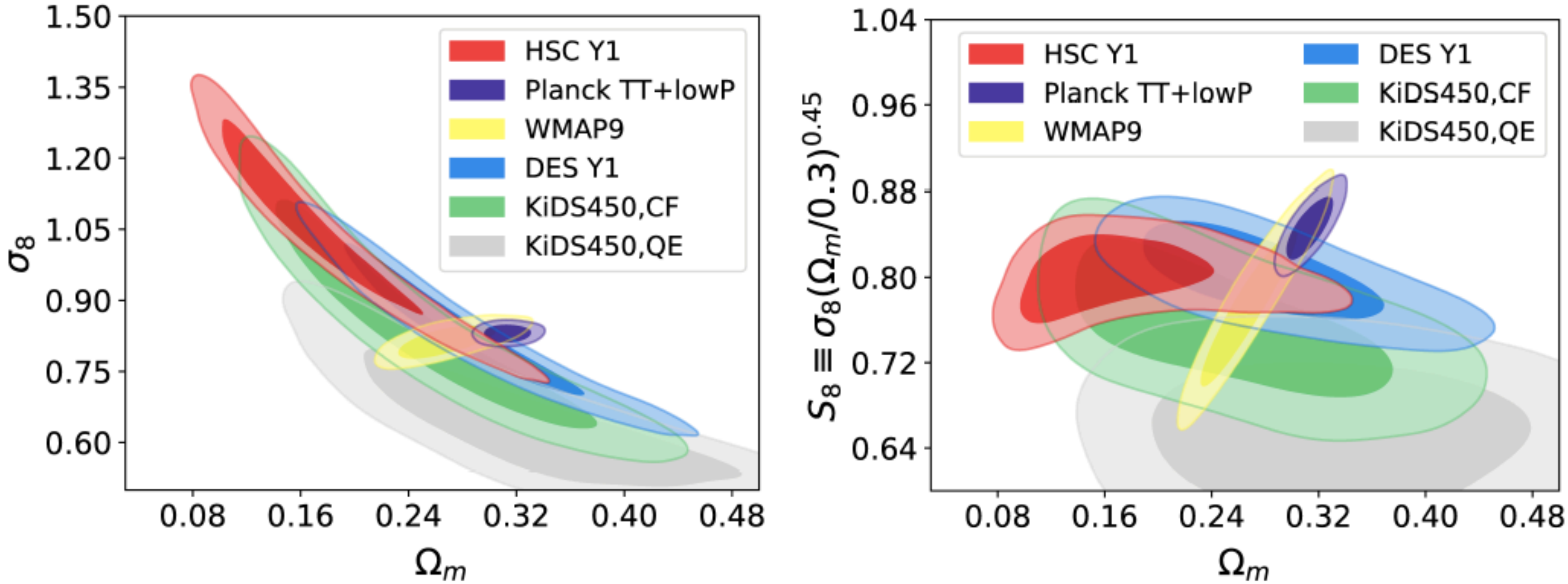
- **Planck 2018** : stable compared to previous releases
- Polarization better understood 0.5 σ systematics uncertainty
- Planck alone fits well ΛCDM, and rather internally consistent
- (Planck + ΛCDM) consistent with latest BAO, SN (Pantheon Scolnic 2018) , RSD, DES lensing 2018
- (Planck + ΛCDM) has slight tension with DES joint probes
- (Planck + ΛCDM) has 3.6 σ tension with H_0 from SH0ES

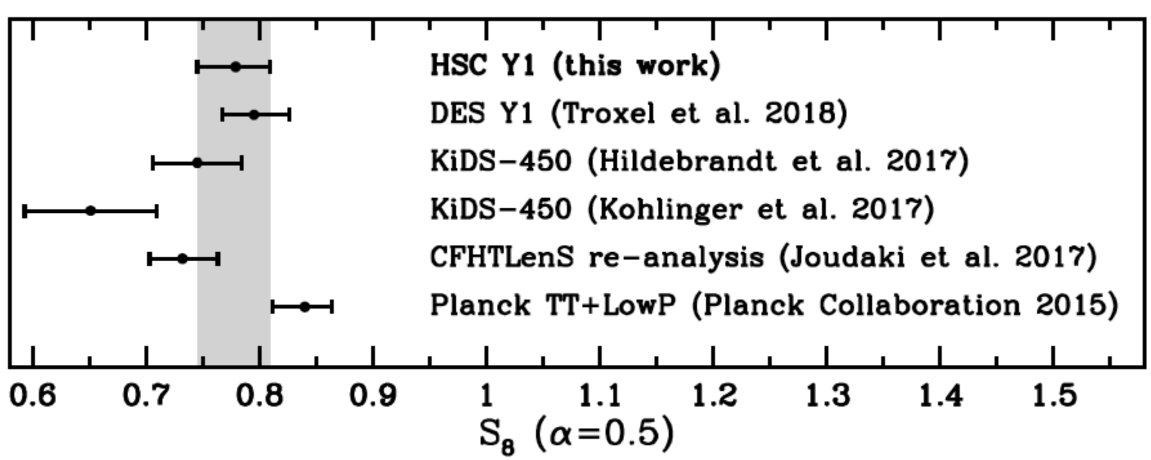


DES lensing
Planck lensing
DES lensing+Planck lensing
Planck TT,TE,EE+lowE
DES joint
1.2
1.0
0.8
0.6
σ_8
0.2
0.3
0.4
0.5
Ω_m

Latest HSC WL data

Hikage et al. 1809.09148

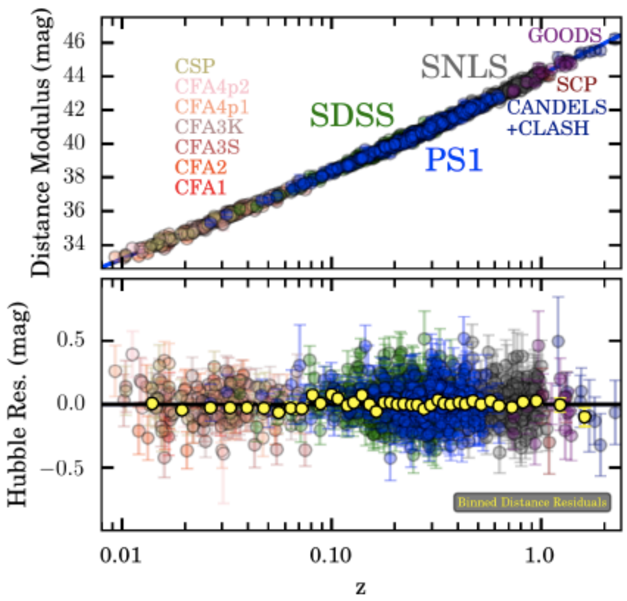




Pantheon SN IA sample

Scolnic et al, 2018

+ subset of 279 PS1 SN Ia (0. 03 < z < 0.68)
+ SDSS, SNLS, various low-z and HST
total of 1048 SN Ia 0. 01 < z < 2.3,



+ Planck 2015 CMB in wCDM model
Ωm = 0.307 +/-0. 012
w = 1. 026 +/- 0. 041

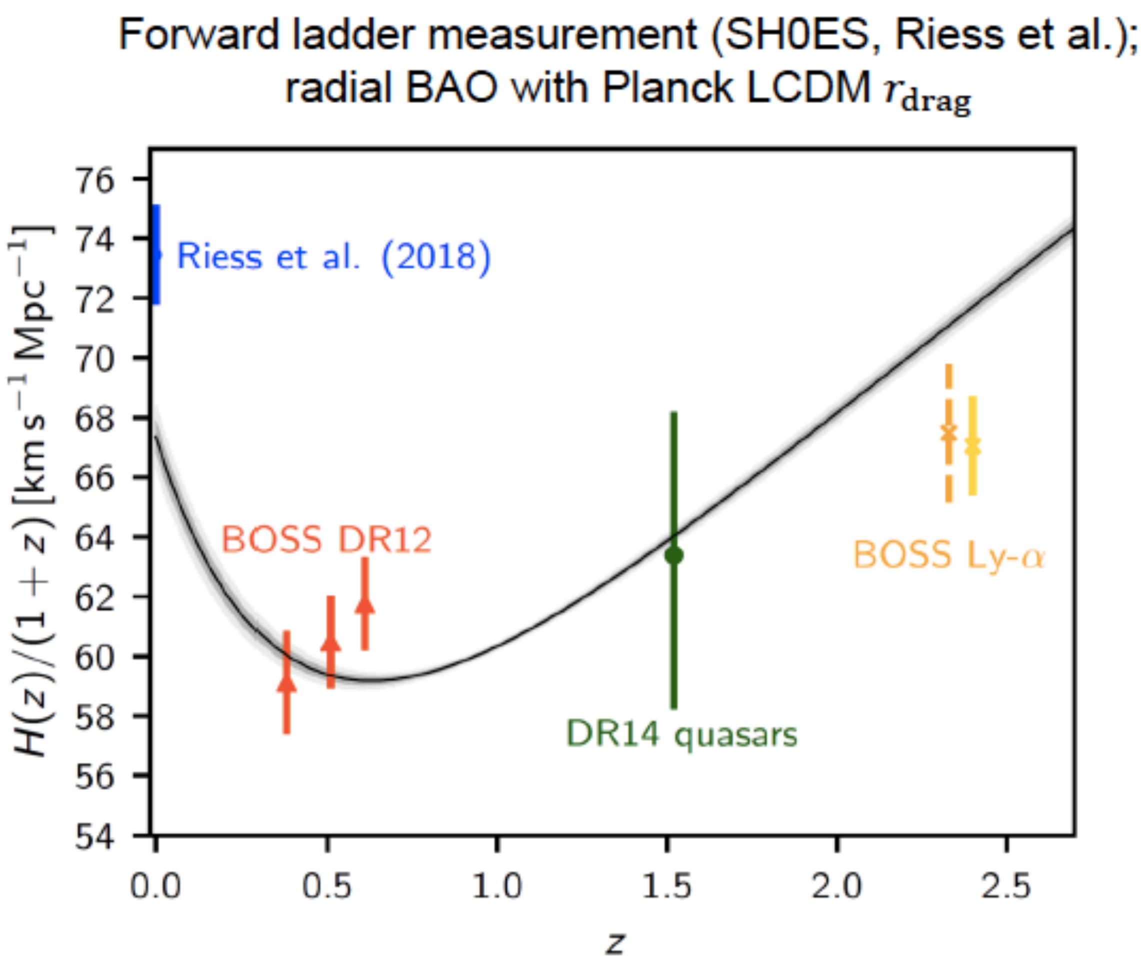
+ SN and CMB + BAO and local H0,
in w0wa CDM model.

w0 = 1. 007 +/- 0. 089
wa = 0: 222 +/- 0. 407

- Tension with previous PS1 and low-z SNe has diminished thanks to an increase of 2 in PS1 sample, improved calibration and photometry, and stricter light-curve quality cuts.
- Systematic O(stati) uncertainties - primarily due to modeling the low-z sample.

3.6 σ tension between (Planck + ΛCDM) and SH0ES -2018

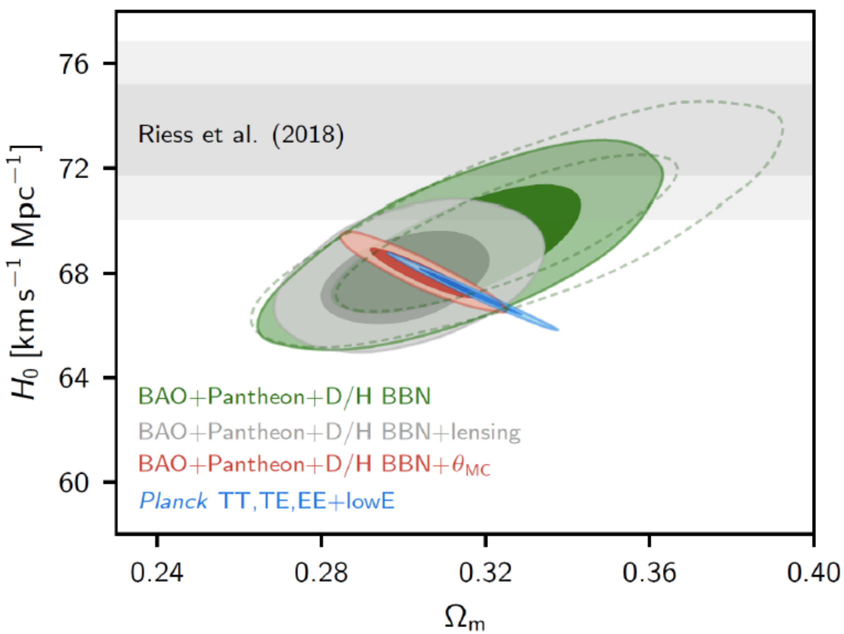
Anthony Lewis
2018

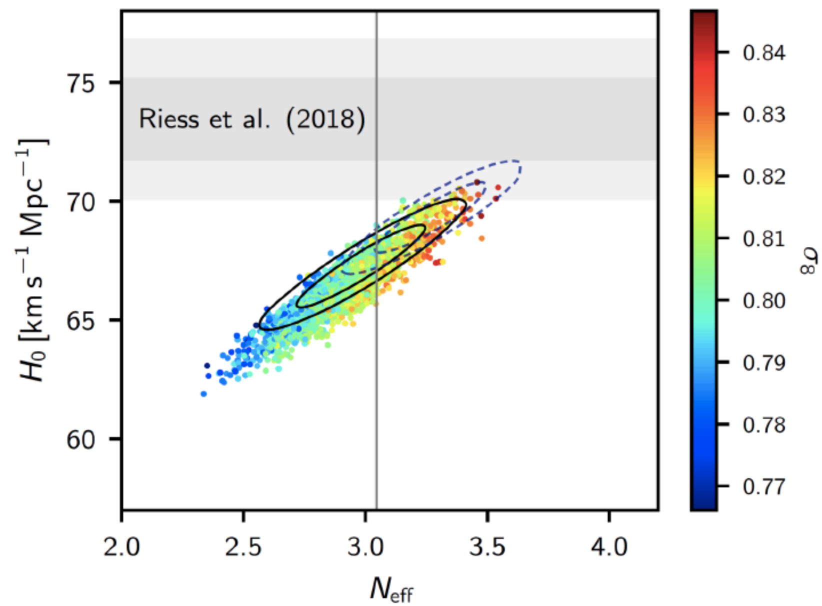


Planck LCDM: $H_0 = (67.36 \pm 0.54)$ km/s/Mpc

Riess et al 2018b: $H_0 = (73.52 \pm 1.62)$ km/s/Mpc

3.6 σ tension between (Planck + ΛCDM) and SH0ES -2018





SH0ES 2018

Riess et al. 2018, 1804.10655

MILKY WAY CEPHEID STANDARDS FOR MEASURING COSMIC DISTANCES AND APPLICATION TO Gaia DR2: IMPLICATIONS FOR THE HUBBLE CONSTANT

- HST photometry of 50 long-period, low- extinction Milky Way Cepheids/ 5 millimags per observation.
- Gaia DR2 parallaxes simultaneously constrain the cosmic distance scale and measure the DR2 parallax zeropoint offset appropriate for Cepheids.
  –46±13 µas or ± 6 µas for a fixed distance scale,

- Best-fit distance scale is 1.006 ± 0.033 , relative Riess et al. (2016)

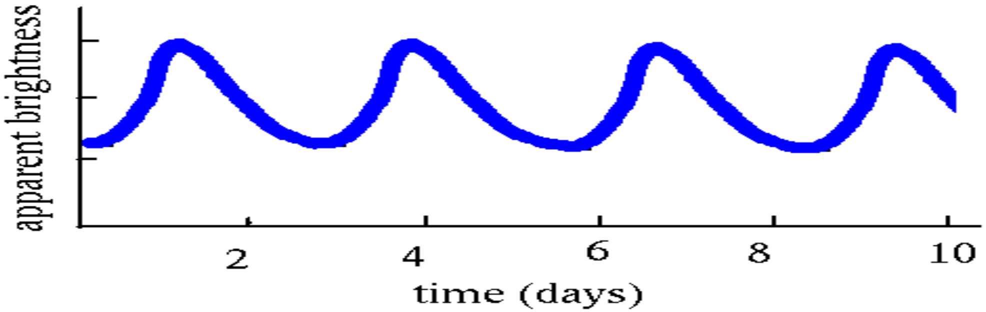
with H_0 = 73.24 kms–1Mpc–1

iinconsistent with the scale needed to match the Planck 2016 CMB data combined with CDM at the 2.9σ confidence level (99.6%).

Cepheids

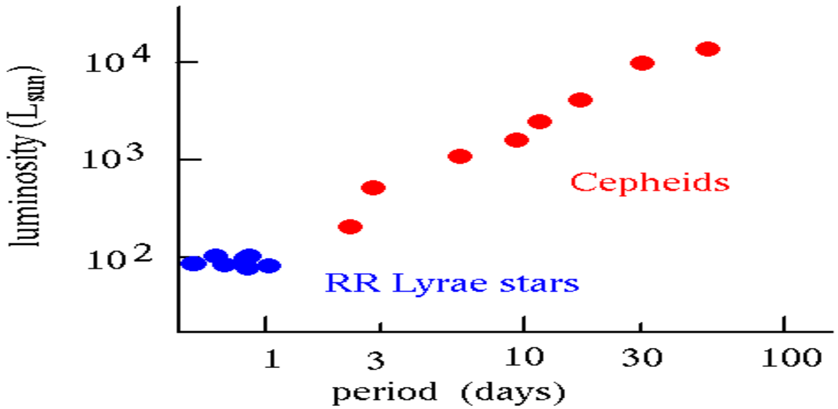
Variable stars

• Pulsation /size (+luminous +larger)



1907, Henrietta Leavitt (1868-1921), Harvard Observatory

Relations Luminosity- Period (discovered in SMC)



• The larger and more luminous Cepheids have the larger periods (from 2 to 150 days)

• Difficult Equilibrium between Core and surface radiation power

• Superior layers too opaque: pressure accumulates under photosphere, the star gathers volume

• External layers evaporate, become more transparent, energy is evacuated, underlying pressure falls, the star contracts

Cepheids

- Luminosity measured to ~10%
- Primary distance indicators most important for nearby Galaxies

•2 populations of Cepheids (Hubble's error)

•Type 1: classical,

~4 brighter than type 2,

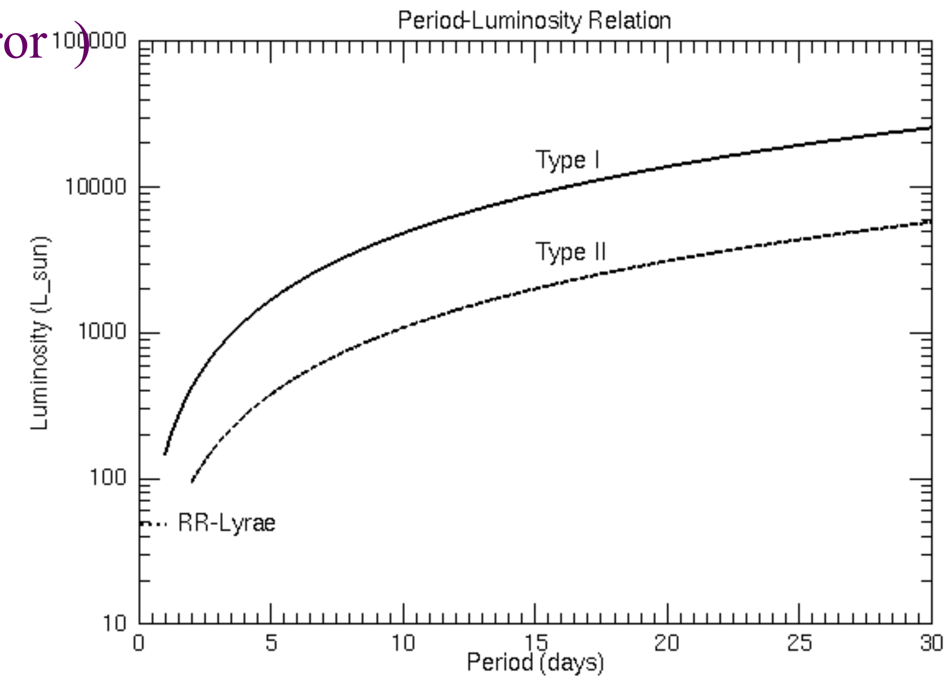
important metallicity, in disk

•Type 2: Older stars, low metallicity,

in halos

- Distances < ~ 30Mpc

•Beyond : used to calibrate secondary methods



Discussion: Riess et al. vs Shanks et al.

1810.02595 **GAIA Cepheid parallaxes and `Local Hole' relieve H0 tension**

181003526 **SEVEN PROBLEMS WITH THE CLAIMS RELATED TO THE HUBBLE TENSION IN ARXIV:1810.02595 Riess et al.**

1) The main sequence fitting of cluster stars, used as distance indicator, is unrelated to SH0ES H0 measurements

2) Cepheids used fully saturate GAIA detector, and produce unreliable parallaxes;

3) The fixed parallax offset is derived for sources with extremely different colors and magnitudes but it is known to depend on source magnitude and color but;

4) ignoring the uncertainty in this offset;

5) ignoring the other geometric sources of Cepheid calibration,

6) because of the increase in 2 that the alleged void would entail in SN measurements in the Hubble flow,

7) because it would represent a 6 σ fluctuation of cosmic variance between the local and globally measured expansion, requiring us to live in an exceedingly special location.

But all local geometrical measurements agree!

- **Cepheids and SNIa. improvement in stat. and syst.**
- Masers in NGC 4258 (Humphreys et al. 2013),
- Detached eclipsing binaries (DEBs) in the Large Magellanic Cloud (LMC) Pietrzynski et al. 2013,
- Trigonometric parallaxes of Milky Way (MW) Cepheids (Benedict et al.2007; van Leeuwen et al. 2007; Riess et al. 2014; Casertano et al. 2016)
- Tip of the red giant branch (TRGB) to reach SN Ia hosts, ➔ changes of < 0.5% for the same sources (Jang & Lee 2017; Jang et al. 2017
- Dust-insensitive near-infrared SN Ia (NIR, Dhawan et al. 2017)
- Latest Time delays from strong gravitational lensing.

H_0 = 72.8 ± 2.4 $kms^{-1}Mpc^{-1}$ for realistic values of Ω_M

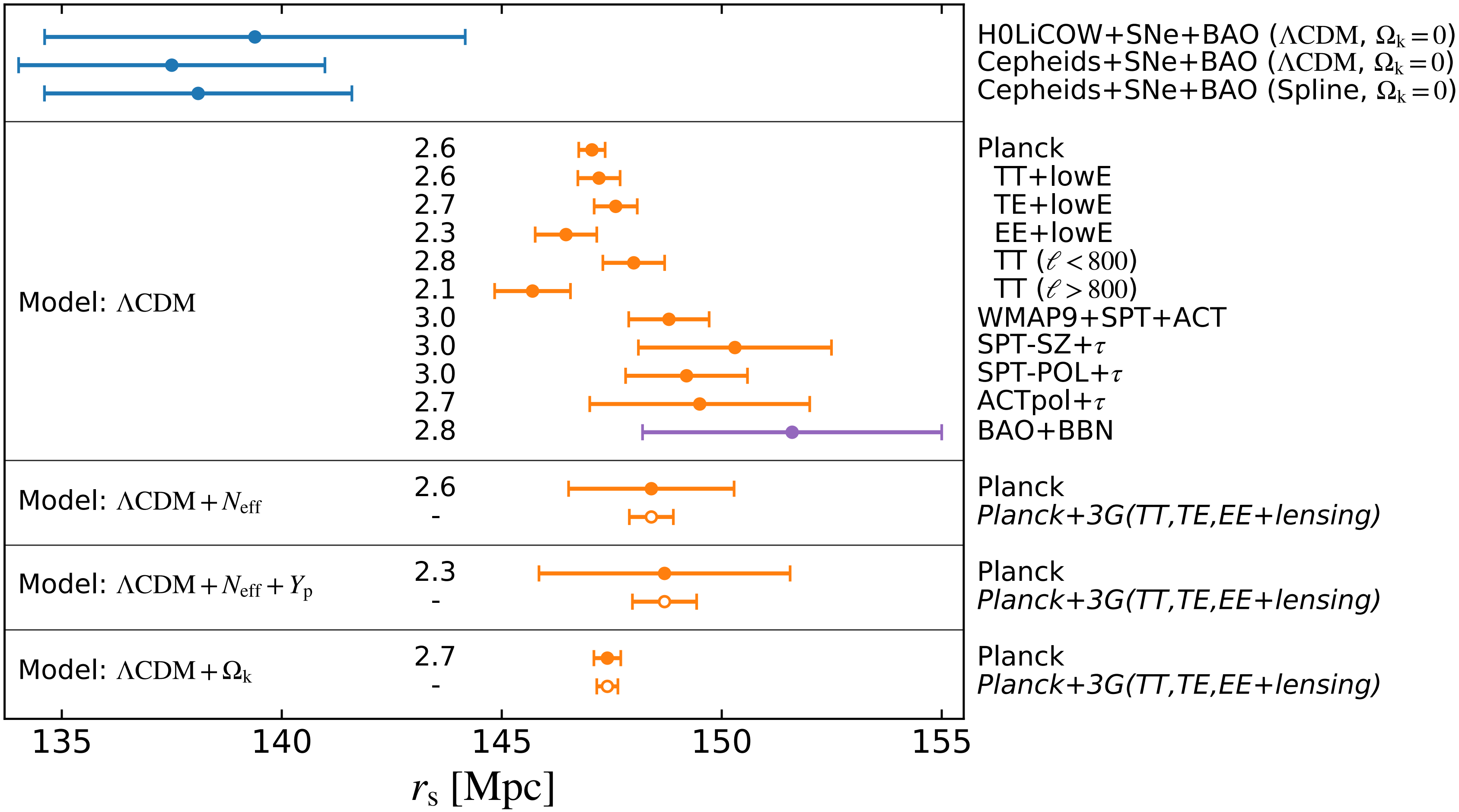
(Bonvin et al. 2017 HOliCOW)collaboration)

What about systematics in Planck?

- Result from Planck is robust to choice of frequency channels
- Combination of BAO, SNIa and CMB data with or without Planck (e.g., WMAP9, Bennett et al. 2013) ➔ low (Planck - like) values of H0
- CDM model + BAO data, + light element abundance (eg baryon-to-photon ratio), without use of any CMB data at all ➔ a Planck-like value of H_0 Addison et al. (2018)

"Sounds Discordant: CLASSICAL DISTANCE LADDER & CDM-BASED DETERMINATIONS OF THE COSMOLOGICAL SOUND HORIZON »

Aylor et al. 1811.00537



➔ Modifications to cosmology at early times, before recombination, not at late times!

What can CSSOS/ Euclid do for H_0?

- SNIa cadence issues
- AGN/Quasar
- Strong Lensing Time delays

not easy – need complementary data

Euclid SN survey priorities

- Basic goal: a significant gain over existing SN surveys
  - In particular SNLS and DES
- Euclid has the potential to provide the first NIR survey for SNe from space
- Provides an independent Euclid probe of cosmology
- With 6 months of observing time, the most interesting option is the “DESIRE “survey
  - Reaches high redshift : up to z ~ 1.5
  - Cannot be done from the ground

arxiv 1409.8562

DESIRE project!

Published by A&A december 2014

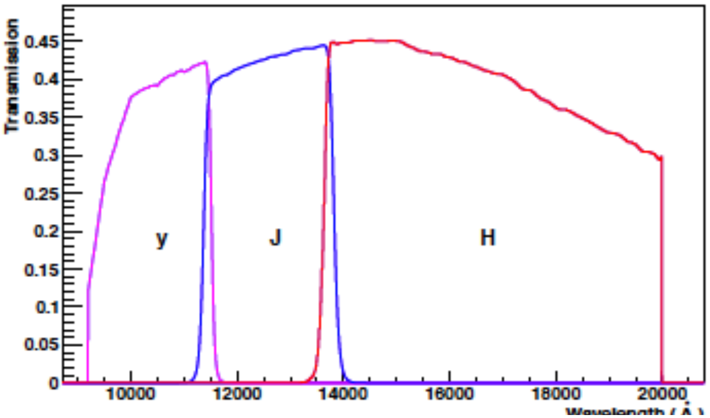
Extending the supernova Hubble diagram to $z \sim 1.5$ with the Euclid space mission

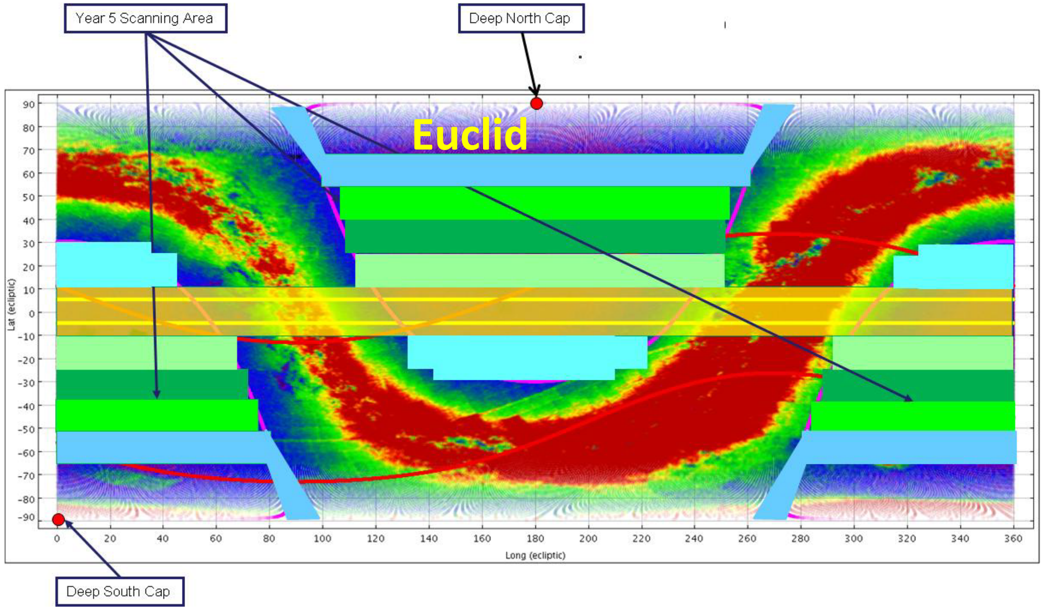
P. Astier[1], C. Balland[1], M. Brescia[2], E. Cappellaro[3], R. G. Carlberg[4], S. Cavuoti[5], M. Della Valle[2,6], E. Gangler[7], A. Goobar[8], J. Guy[1], D. Hardin[1], I. M. Hook[9,10], R. Kessler[11,12], A. Kim[13], E. Linder[14], G. Longo[5], K. Maguire[9,15], F. Mannucci[16], S. Mattila[17], R. Nichol[18], R. Pain[1], N. Regnault[1], S. Spiro[9], M. Sullivan[19], C. Tao[20,21], M. Turatto[3], X. F. Wang[21], and W. M. Wood-Vasey[22]

ABSTRACT

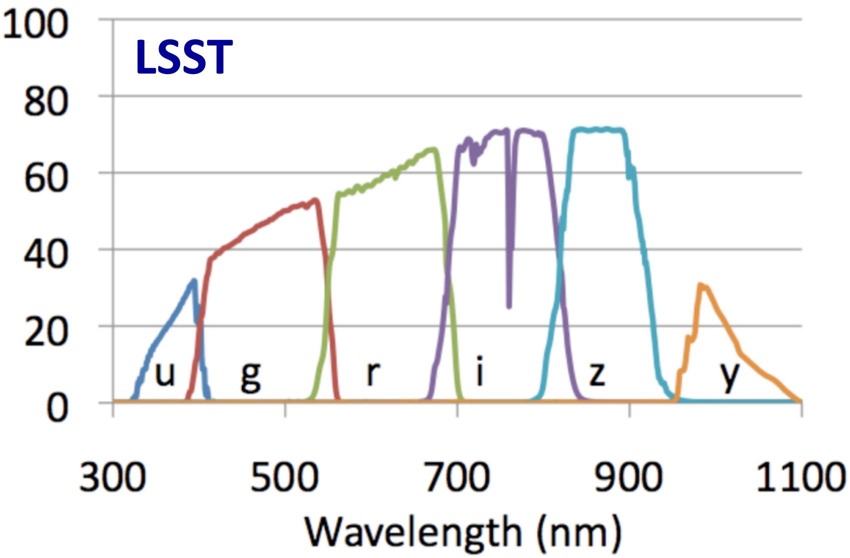
We forecast dark energy constraints that could be obtained from a new large sample of Type Ia supernovae where those at high redshift are acquired with the Euclid space mission. We simulate a three-prong SN survey: a $z < 0.35$ nearby sample (8000 SNe), a $0.2 < z < 0.95$ intermediate sample (8800 SNe), and a $0.75 < z < 1.55$ high-z sample (1700 SNe). The nearby and intermediate surveys are assumed to be conducted from the ground, while the high-z is a joint ground- and space-based survey. This latter survey, the "Dark Energy Supernova Infra-Red Experiment" (DESIRE), is designed to fit within 6 months of Euclid observing time, with a dedicated observing programme. We simulate the SN events as they would be observed in rolling-search mode by the various instruments, and derive the quality of expected cosmological constraints. We account for known systematic uncertainties, in particular calibration uncertainties including their contribution through the training of the supernova model used to fit the supernovae light curves. Using conservative assumptions and a 1-D geometric *Planck* prior, we find that the ensemble of surveys would yield competitive constraints: a constant equation of state parameter can be constrained to $\sigma(w) = 0.022$, and a Dark Energy Task Force figure of merit of 203 is found for a two-parameter equation of state. Our simulations thus indicate that Euclid can bring a significant contribution to a purely geometrical cosmology constraint by extending a high-quality SN Ia Hubble diagram to $z \sim 1.5$. We also present other science topics enabled by the DESIRE Euclid observations.

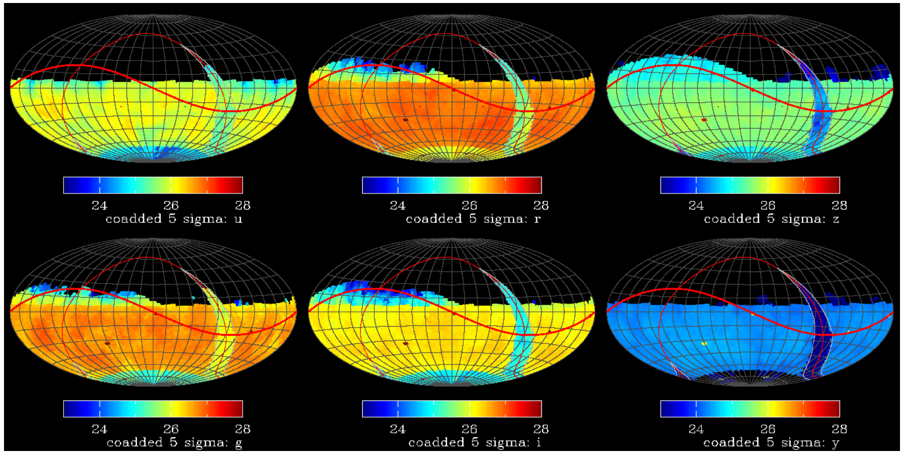
Complementary Observations with LSST





EUCLID NIR + Broad visible bands





DESIRE with EUCLID + LSST

Table 4. Main parameters of the simulated surveys.

	z_{min}	z_{max}	area (deg^2)	duration (months)	events
DESIRE	0.75	1.55	10	2x6	1740
LSST-DDF	0.15	0.95	50	4x6	8800
Low z	0.05	0.35	3000	6	8000

NB: 2* 6 months (use half time → total 6 months up-time)

Table 2. Depth of the visits simulated for the DESIRE survey.

	i	z	y	J	H
Depth (5σ)	26.05	25.64	25.51	25.83	26.08
Exp. time (s)	700	1000	1200	2100	2100

Notes. Depth (5σ for a point source) and exposure times at each visit for a 4-day cadence of the proposed DESIRE joint SN survey. The exposure times for LSST i and z bands assume nominal observing conditions. For Euclid NIR bands, the exposures times are the ones that would deliver the required depth in a single exposure, if such long exposures are technically possible. The S/N calculations are described in appendix A.

DESIRE:

An ultra deep survey!

final stacked depth

28 to 28.5 mag

(AB, 5 σ point source limit)

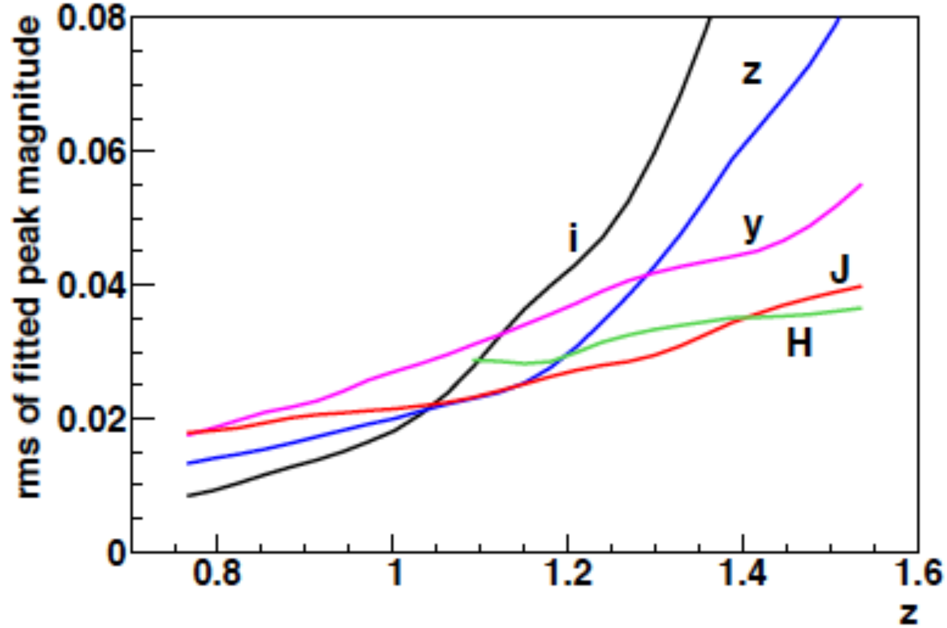


Fig. 5. Precision of light curve amplitudes as a function of redshift for the 5 bands of the DESIRE survey, assuming a 4-day cadence with the exposure times of Table 2. To fulfill the requirements in §2.3, i-band is used up to $z = 1$, z-band up to $z = 1.2$, and distances at $z = 1.5$ rely mostly on J- and H-band. For y, J and H bands, these calculations assume a reference image gathering 60 epochs in Euclid.

FOM > 200

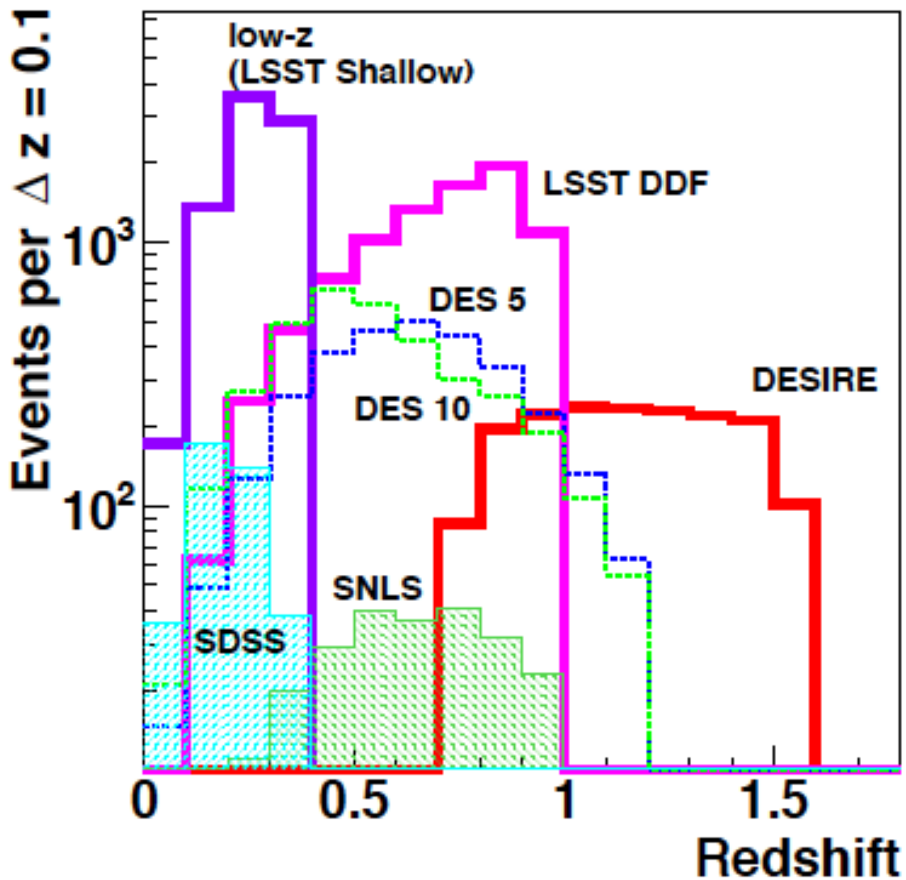


Fig. 12. Redshift distribution of events for various surveys. For the SDSS and SNLS, the distributions sketch the total sample of spectroscopically identified events eventually entering the Hubble diagram. "DES 5" and "DES 10" refer respectively to the "hybrid-5" and "hybrid-10" strategies studied in Bernstein et al. (2012), where the baseline is hybrid-10. "LSST-SHALLOW", "LSST-DDF" and "DESIRE" refer to the three prongs studied in this proposal.

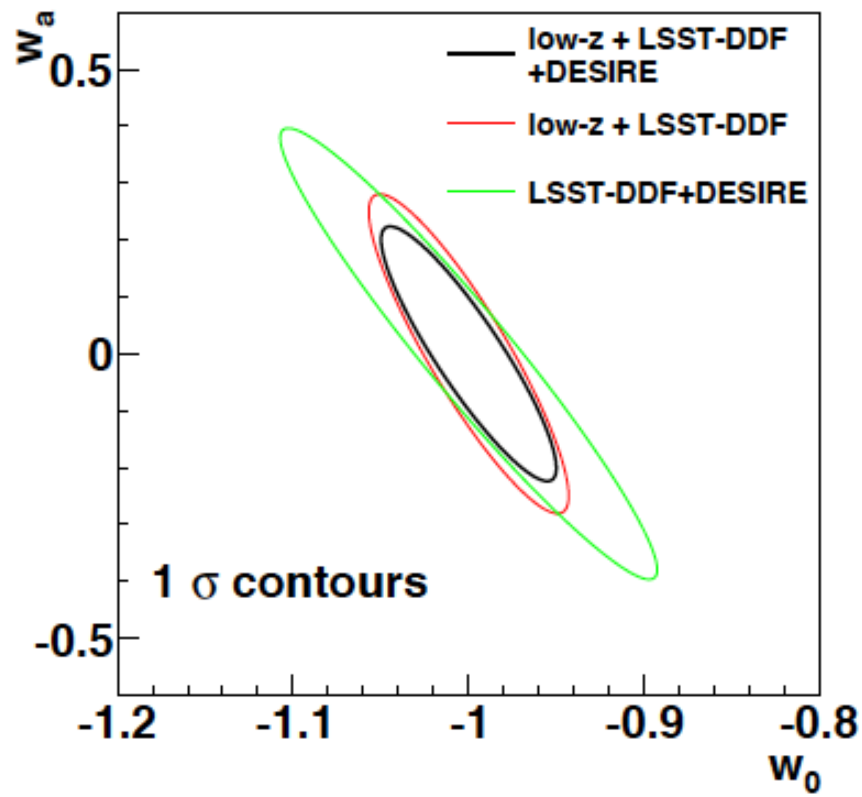


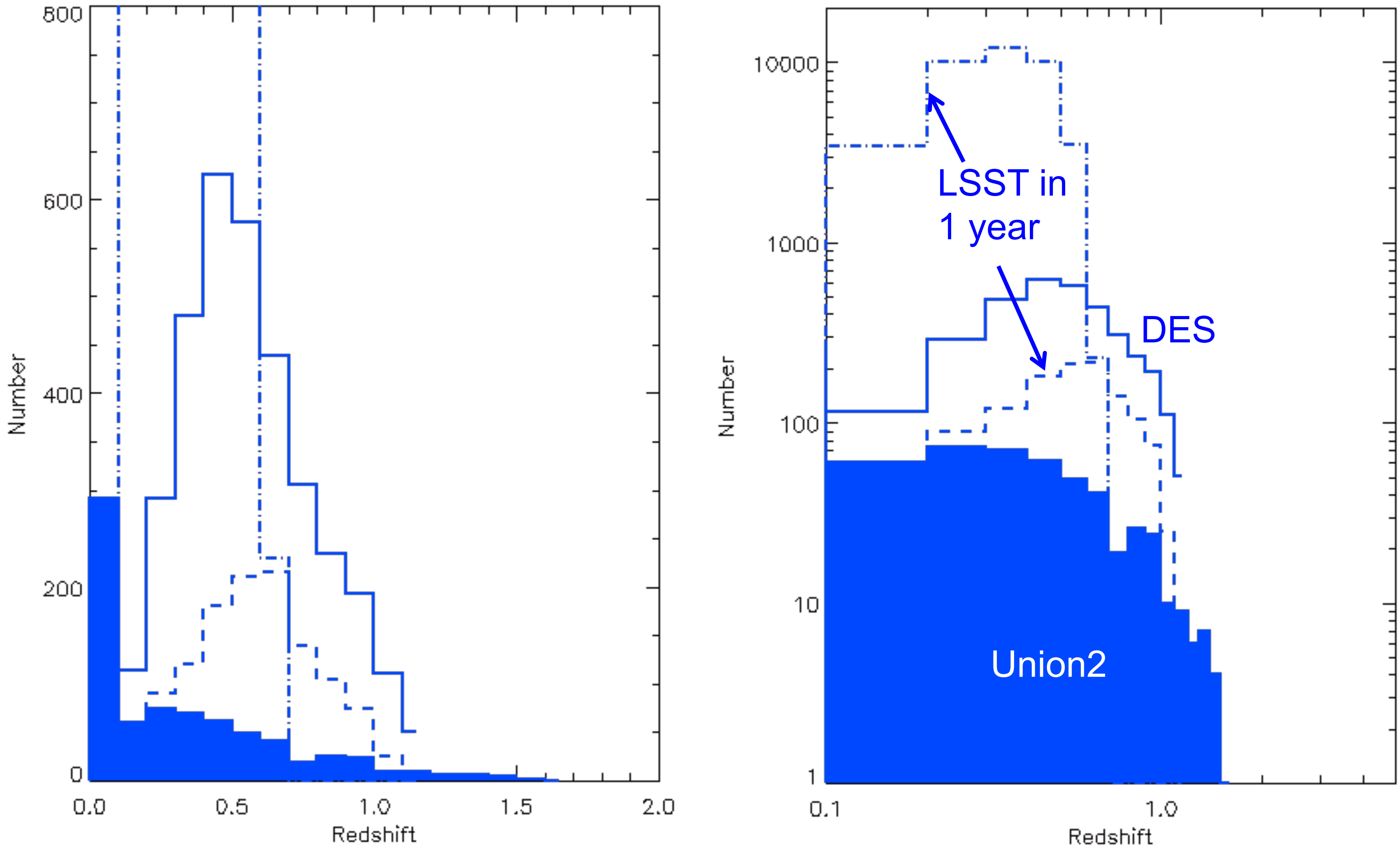
Fig. 9. Confidence contours (at the 1σ level) of the survey combinations listed in Table 5. The assumptions for systematics correspond to the last row o

Table 5. Cosmological performance of the simulated surveys.

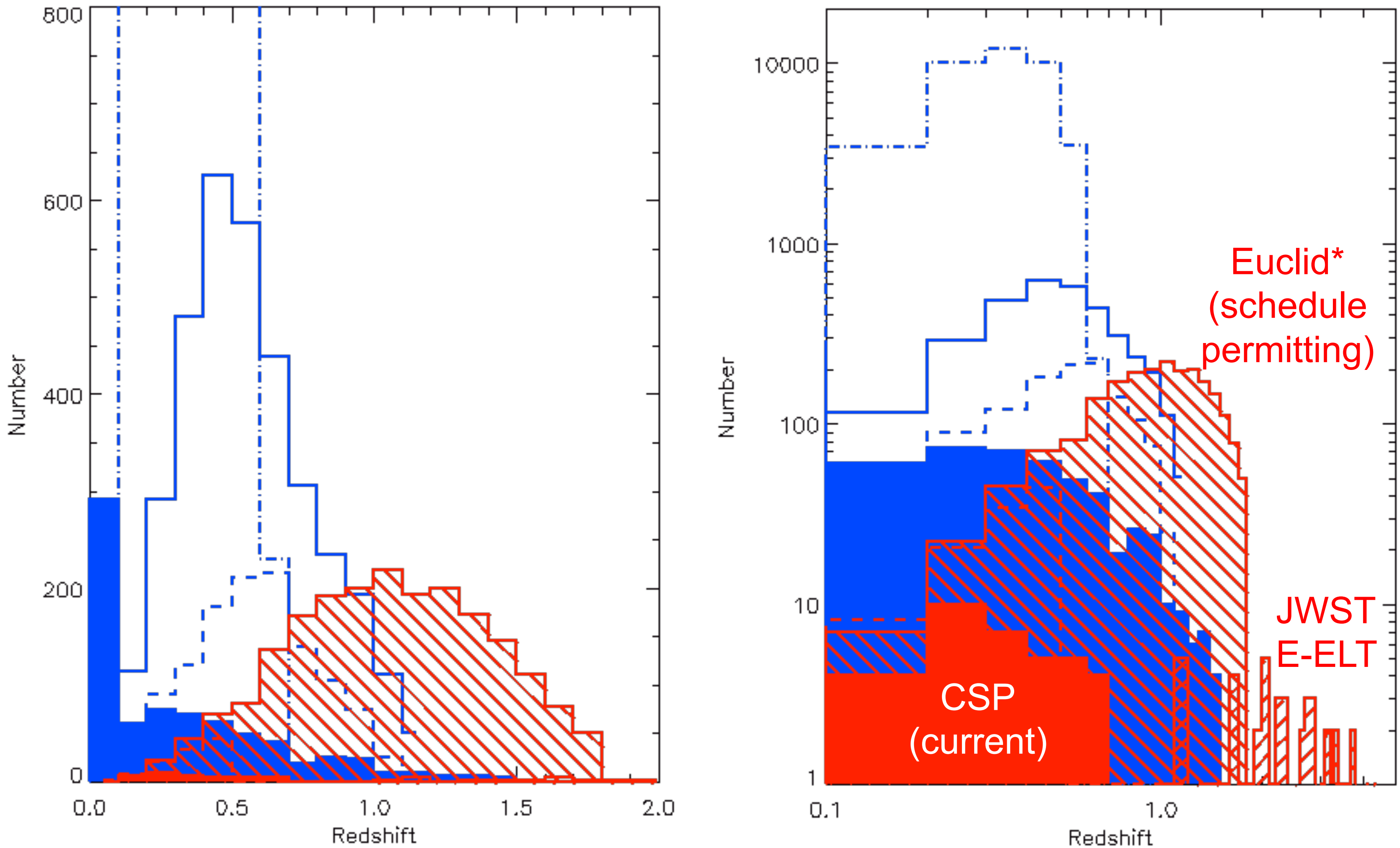
	$\sigma(w_a)$	z_p	$\sigma(w_p)$	FoM
low-z + LSST-DDF + DESIRE	0.22	0.25	0.022	203.2
low-z + LSST-DDF	0.28	0.22	0.026	137.1
LSST-DDF + DESIRE	0.40	0.35	0.031	81.4

Notes. The FoMs assume a 1-D geometrical *Planck* prior and flatness. z_p is the redshift at which the equation of state uncertainty reaches its minimum $\sigma(w_p)$. The FoM is defined as $[Det(Cov(w_0, w_a))]^{-1/2} = [\sigma(w_a)\sigma(w_p)]^{-1}$ and accounts for systematic uncertainties. The contributions of the main systematics are detailed in Table 6.

OPTICAL SN samples



OPTICAL and NIR SN samples



Euclid and Strong Lensing

- Euclid derives the mass function of galaxy clusters (with eROSITA, Planck and SZ),
- over 10^5 strong lensing systems
- Gravitational lensing + NIR photometry of lensing sources :
relationship between light, baryons and dark matter between galaxy and super cluster scales as function of look-back time and environment.
- mass distribution in the central regions can be studied best by modelling strong lensing
- the rare radial arcs constrain the local slope of the density profile,
- tangential arcs place tight limits on the enclosed projected mass.
- With more modelling the morphology and distribution of the multiply-lensed images can provide direct constraints on the presence of substructure or constrain the density profile with high precision (e.g. Smith et al., 2009; Jullo & Kneib, 2009; Meneghetti et al., 2010)
- precise mass modelling can be used to probe the balance between dark and luminous matter, as a function of radial distance and for different galaxy types (e.g. Treu & Koopmans, 2004; Auger et al., 2010; Treu et al., 2011).
- By combining weak and strong lensing it is possible to extend the studies mentioned above over two decades in size (e.g. Gavazzi et al., 2007).
- Since lenses will mainly be found up to z~1, the measurements cover the stellar-to-dark matte evolution over half of the Hubble time (Treu & Koopmans, 2004).
- This dramatic increase of the number of strong galaxy-galaxy lens systems means that surface brightness anomalies (e.g. Koopmans, 2005) might become the main mode to detect mass-substructure in galaxies at cosmological distances.

Euclid and Strong Lensing

Three main classes of lenses:

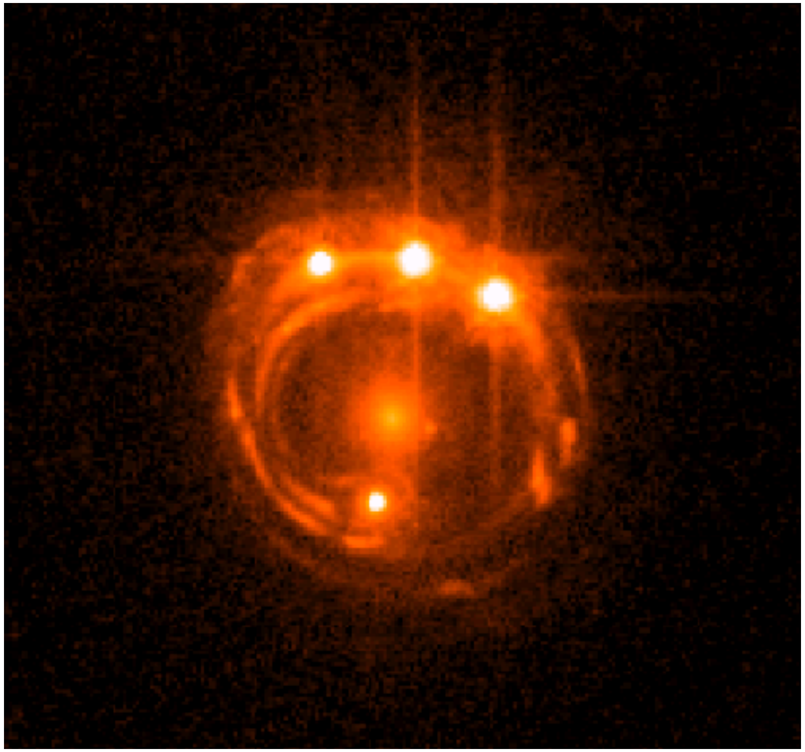
- Individual massive galaxies
- Galaxies in groups/clusters
- Massive galaxy clusters
- Cosmic strings ?

General expectations:

- Galaxies lensed by galaxies: 10/sq deg or O(10^5) for Euclid 15000 sq deg
- QSO lensed by Galaxies : 10^3
- Clusters/groups with giant arcs:

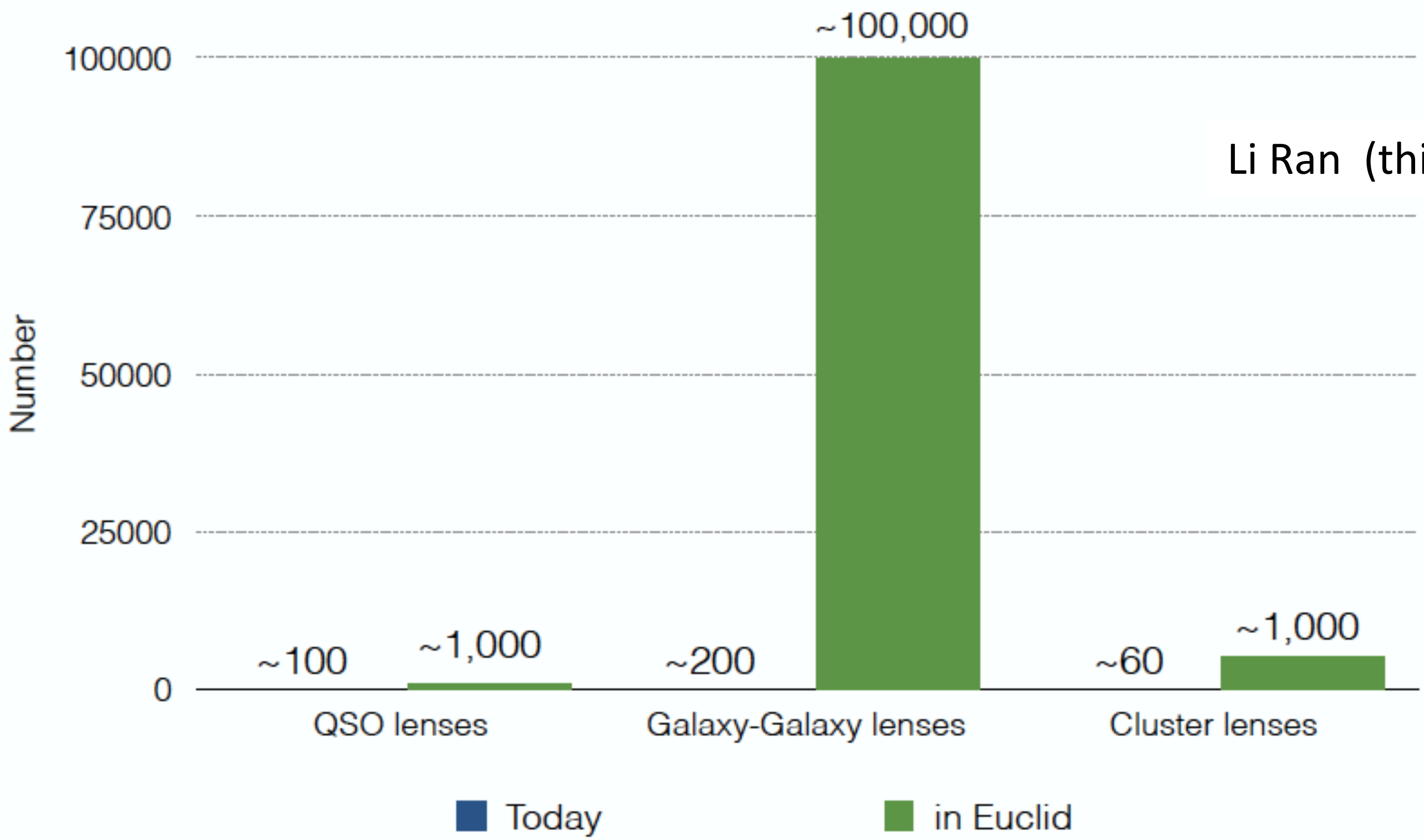
0.5/sq deg or 7500 for Euclid

- Clusters with many multiple images: 100



Example of a strong gravitational lens. quasar RXJ1131-123 is seen quadruple by Hubble Space Telescope,

Numbers of known strong lenses



Li Ran (this morning)

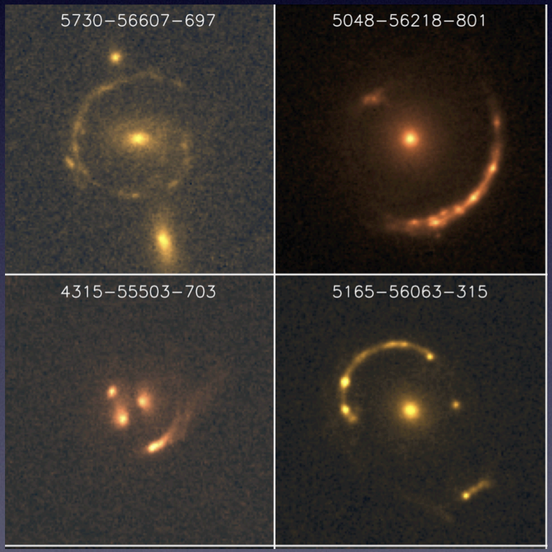
Future Data Sets : KIDS, DES, Pan-Starrs, LSST, Euclid

Metcalf, 2015

Expectation for CSS-OS

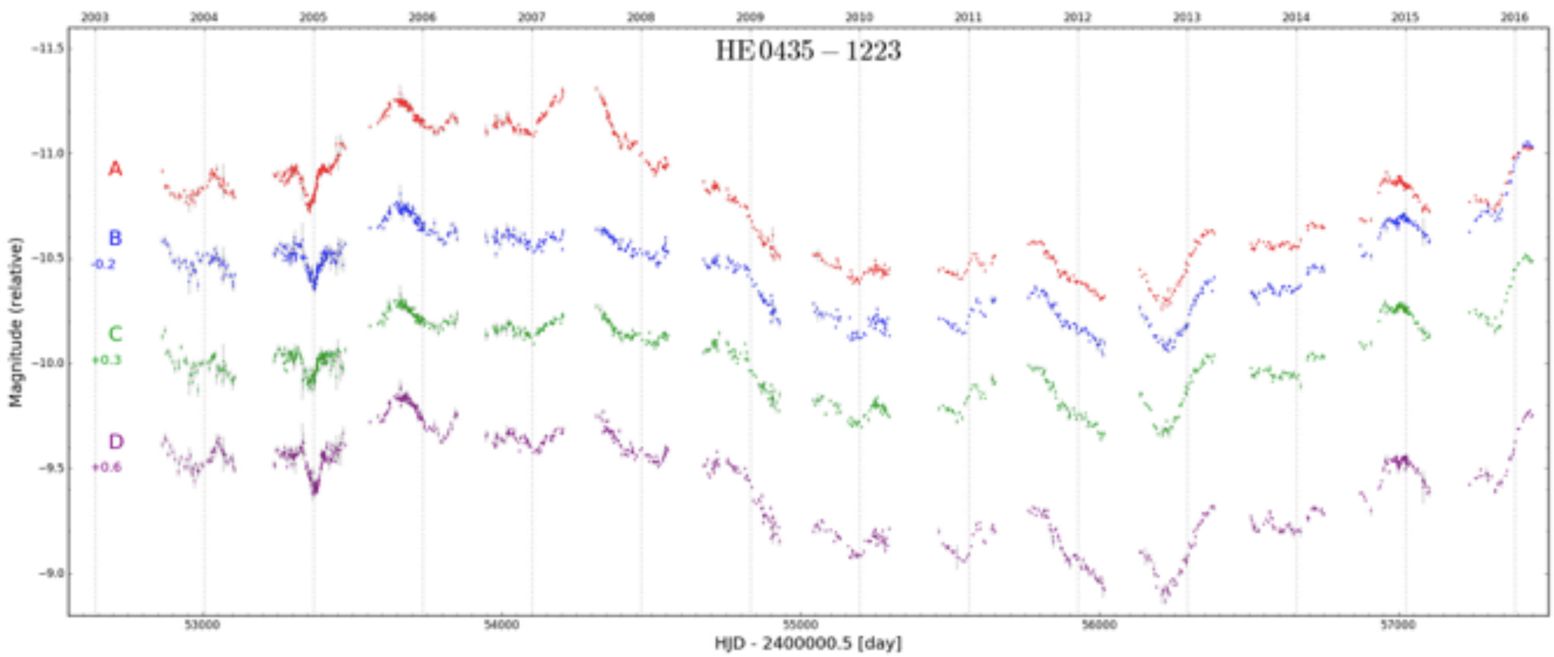
- ~100000 galaxy scale strong lens systems (currently ~400), Including ~1000 double lens system
- Hundreds of massive clusters with many multiple images
- Accurate photo-z for both lens and source.

Provide by Yiping Shu



Challenges for SL determinations of H_0

- Determination of Time delays: cadence and time



13-year light curve of HE0435-1223 Time delay with 6.5% uncertainty

- Need to measure/model precisely lens environment
  - Precise imaging
  - Spectroscopy for source and lens redshift
  - Velocity dispersion to mitigate effects of mass sheet degeneracy

Conclusions **for SL in Euclid** : Metcalf, 2015

- Future surveys will increase the number of known strong lenses by orders of magnitude.

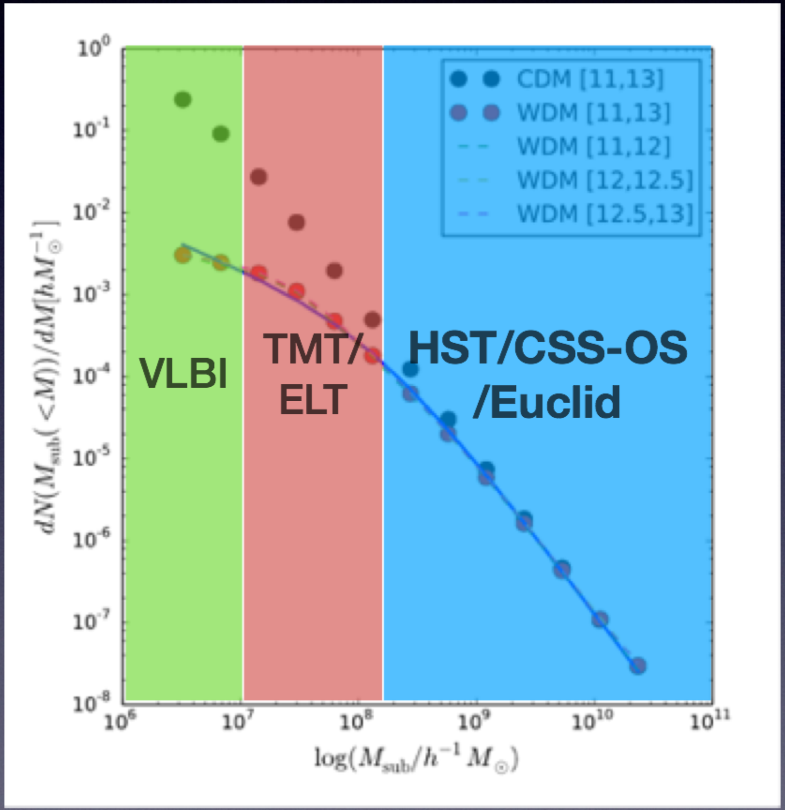
- These lenses will tell us many things about the distribution of matter around galaxies, groups and clusters - small scale structure, separation between dark matter and baryons or possible deviations from GR.

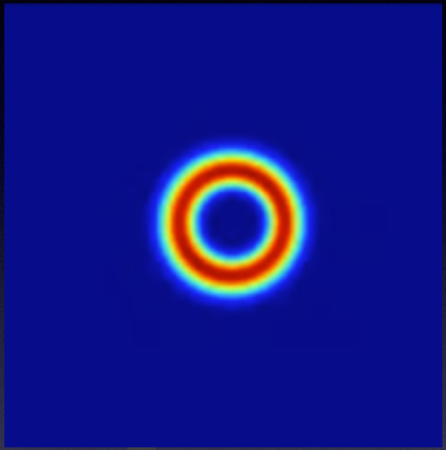
- They will tell us something about cosmology, but it will always be limited by modelling systematics and assumptions about the lenses' mass distribution.

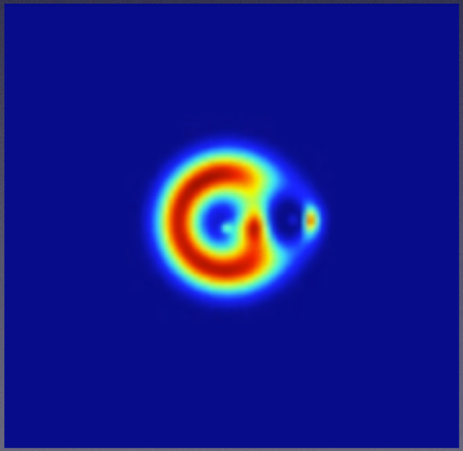
- New tools are being developed to find and analyse strong lenses on a much larger scale.

Li Ran (this morning)

DM on small scales: Substructure detection



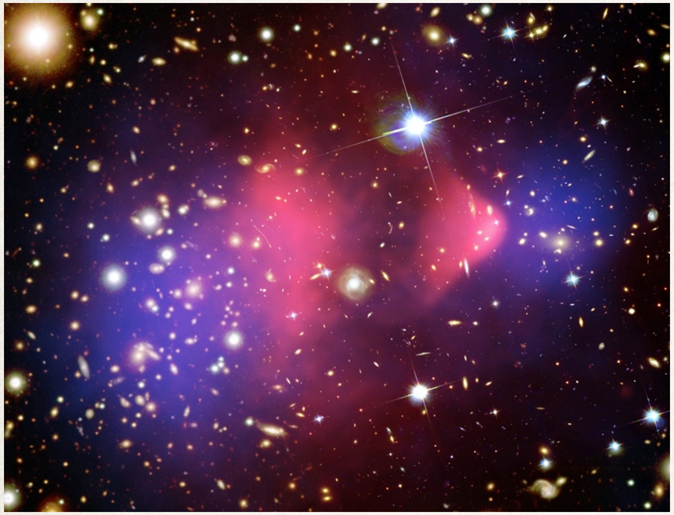


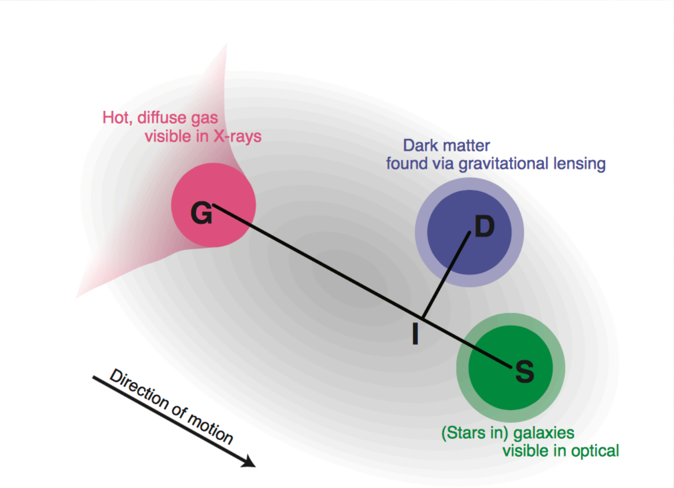


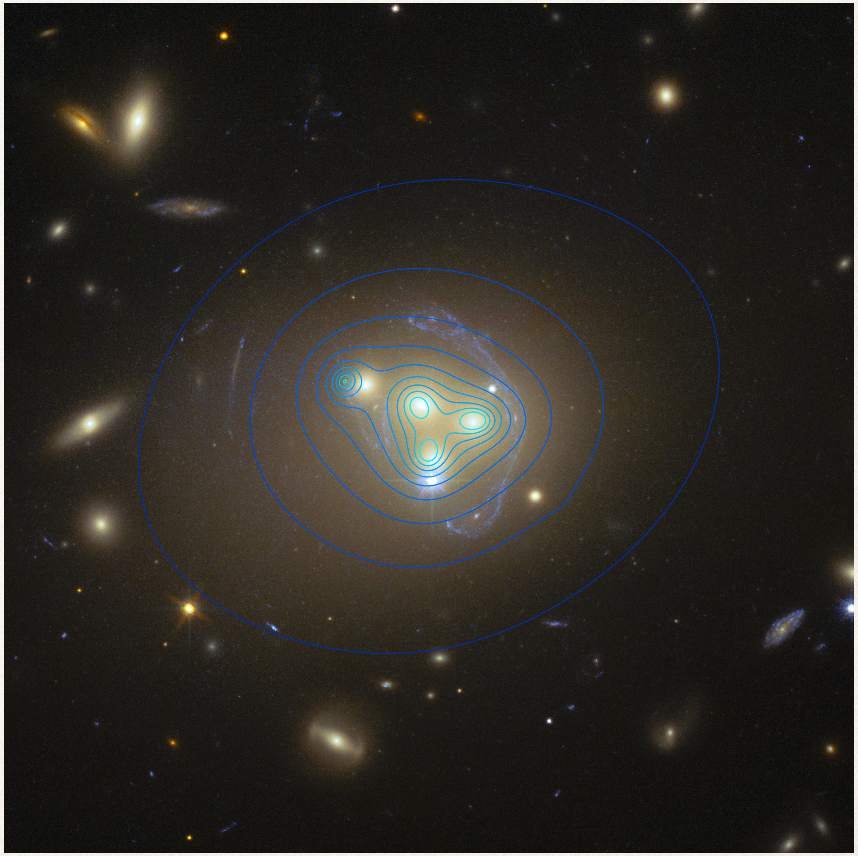
Li et al. 2016 arxiv 1512.06507
CDM vs 3 keV WDM

Li Ran (this morning)

Self-interacting dark matter?





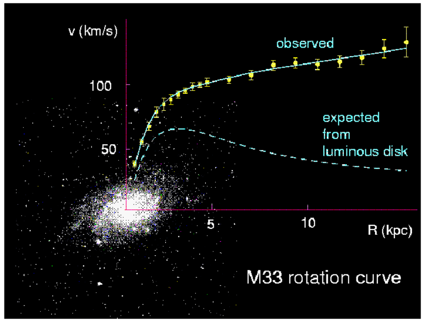


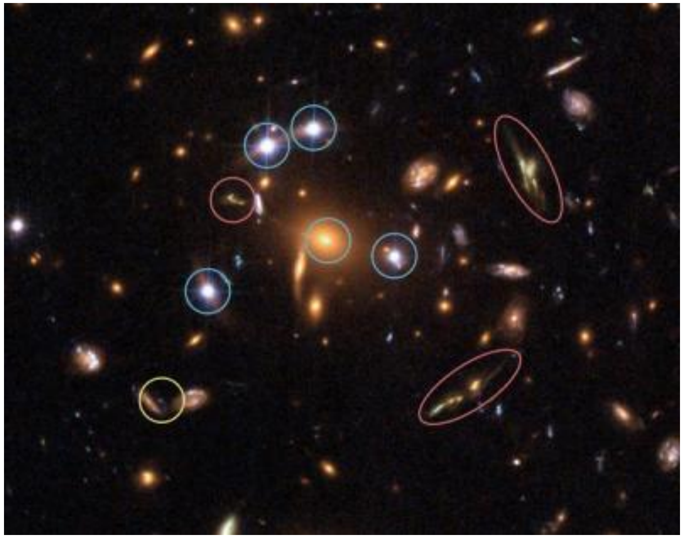
Galaxy cluster Abell 3827
offset is 1.62+0.47 kpc ?

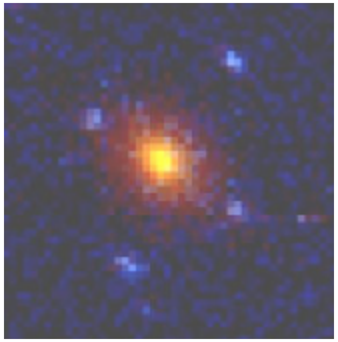
Massey et al. 2015

Wealth of Evidence for DM

- Galaxy rotation curves (V. Rubin)
- Dynamics of galaxy clusters (Zwicky)
- Gravitational lensing mass reconstruction



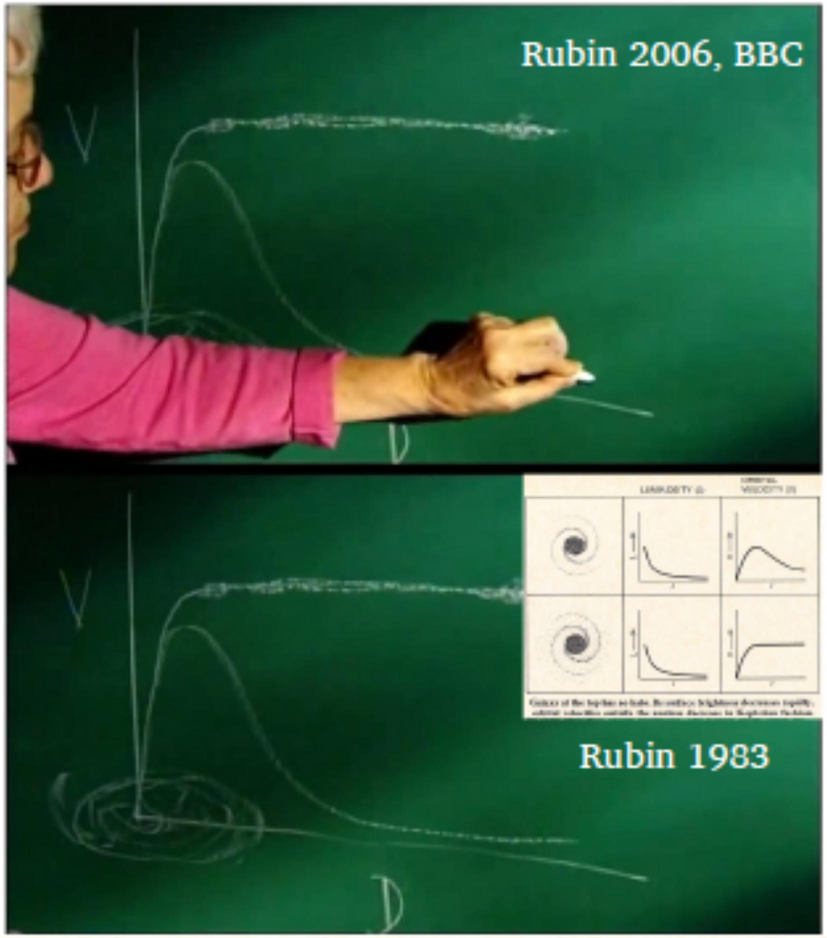




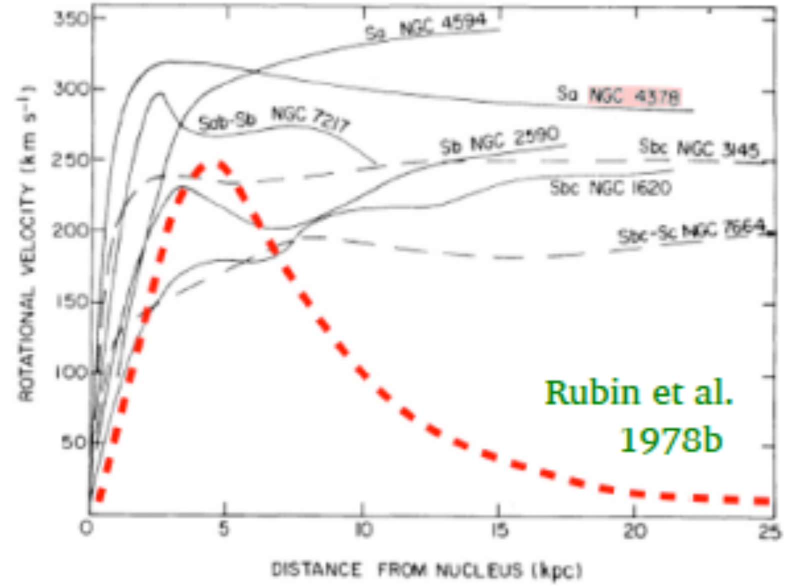
- Bullet cluster (Clowe+,2006)

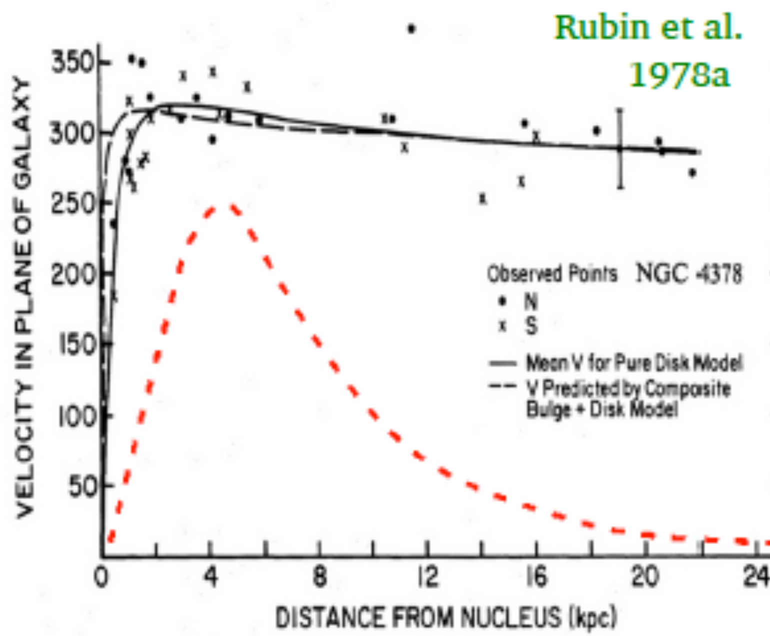
DM: some revisits

Rotation curves : what is often said [incorrectly] to be expected



Galaxy at the top has no halo. Its surface brightness decreases rapidly, orbital velocities outside the nucleus decrease in Keplerian fashion.



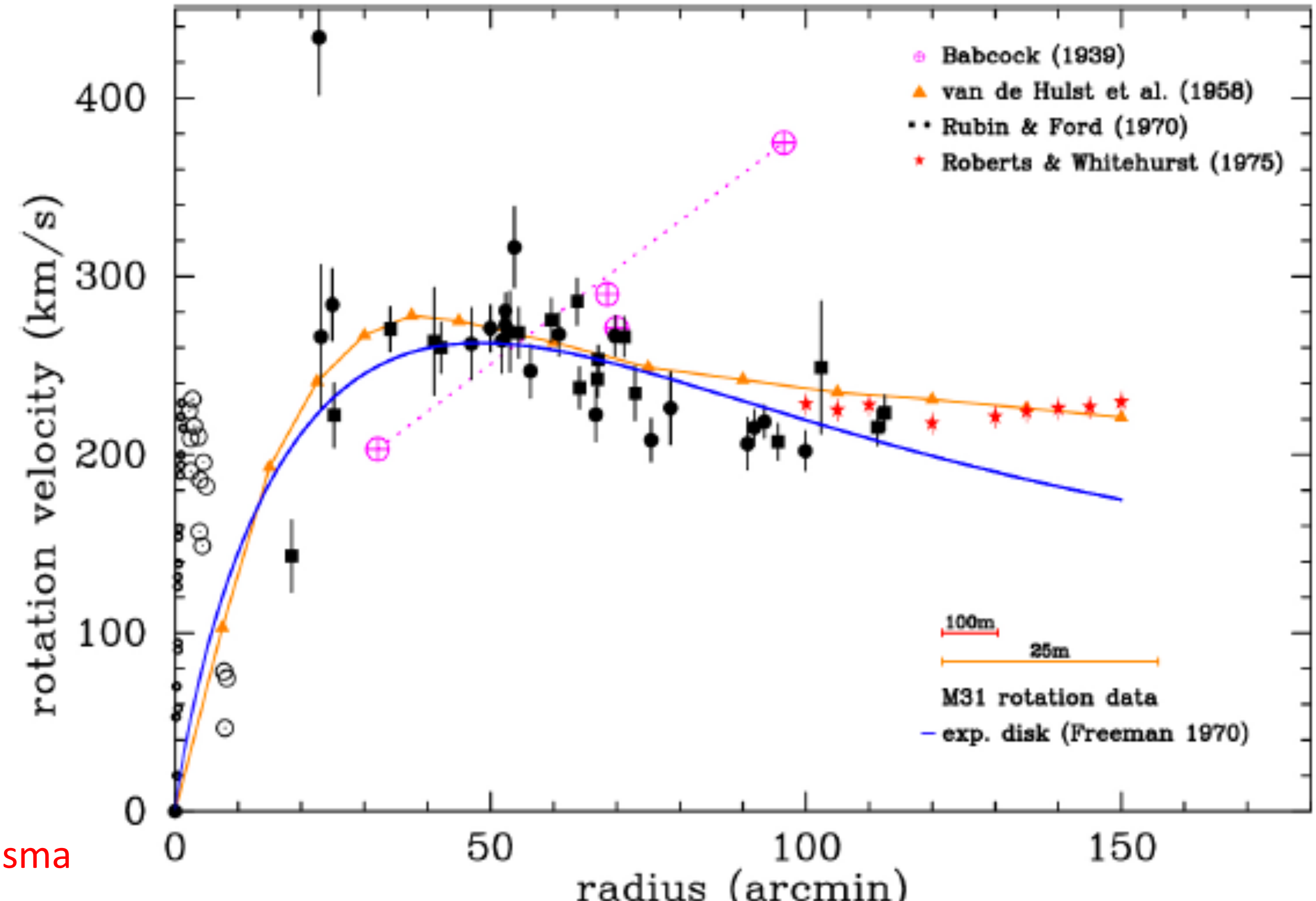


Keplerian behaviour just outside the nucleus can NOT be expected

A. Bosma

Freeman 1970, appendix For NGC 300 and M33, the 21-cm data give turn-over points near the photometric outer edges of these systems. These data have relatively low spatial resolution; if they are correct, then there must be in these galaxies additional matter which is undetected, either optically or at 21 cm. Its mass must be at least as large as the mass of the detected galaxy, and its distribution must be quite different.

M31 – Need for dark matter based on radio data



A. Bosma

Rotation curve analysis

From data to mass models

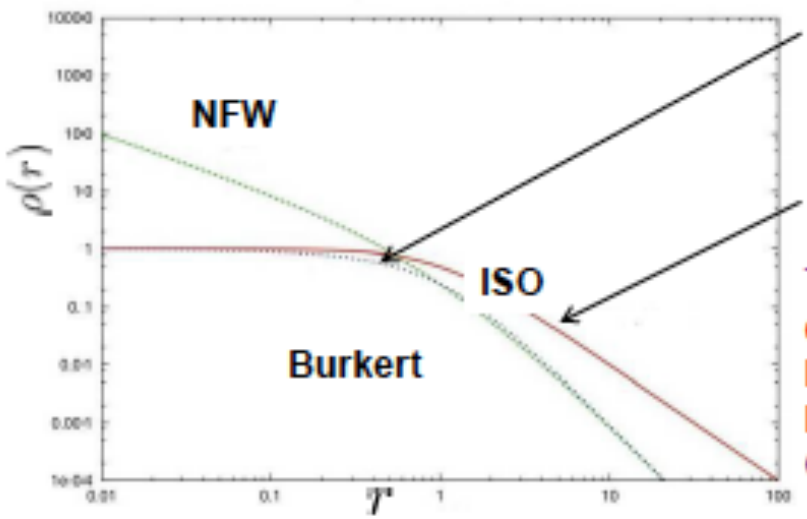
$$V^2(R) = V^2_{halo}(R) + V^2_{HI}(R) + V^2_{disk}(R)$$

observations = model

- V^2_{disk} **from I-band photometry**
- V^2_{HI} **from HI observations**
- V^2_{halo} **different choices for the DM halo density**

Dark halos with central constant density (Burkert, Isothermal)

Dark halos with central cusps (NFW, Einasto)



$$\rho(r) = \frac{\rho_0}{(1 + r/r_0)(1 + (r/r_0)^2)}$$

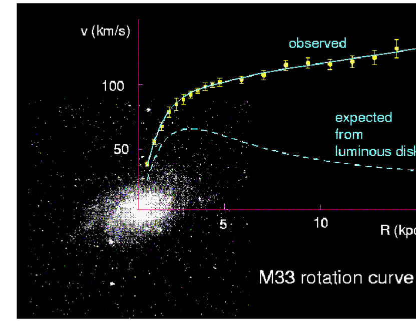
$$\rho(r) = \frac{\rho_0}{1 + (r/r_0)^2}$$

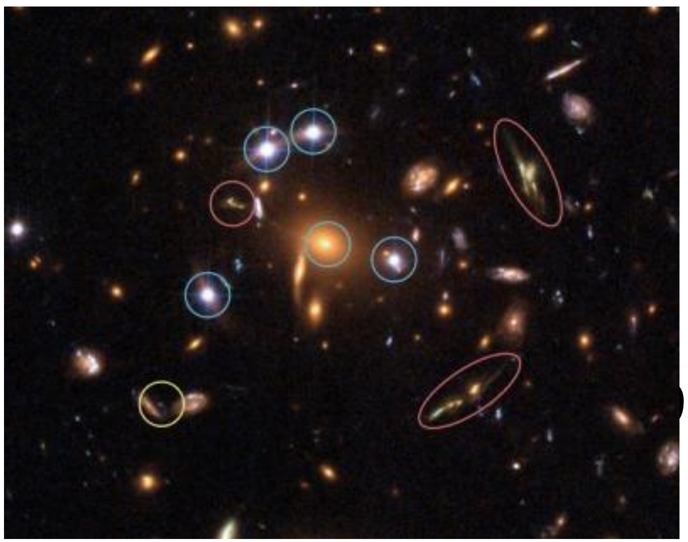
The mass model has 3 free parameters:
disk mass
halo central density
Halo core radius (length-scale)
Obtained by best fitting method

P. Salucci, NAOC 2014

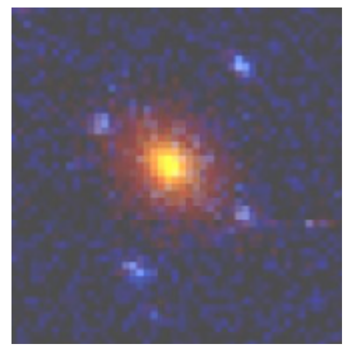
Wealth of Evidence for DM

- *Galaxy rotation curves* (V. Rubin) ~~Bosma~~ (HI)
- *Dynamics of galaxy clusters* (Zwicky)
- *Gravitational lensing mass reconstruction*





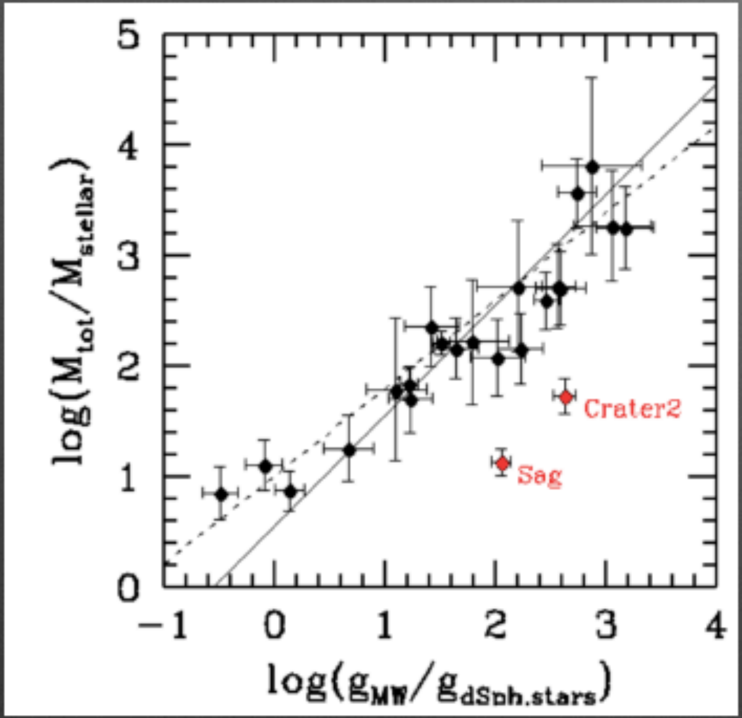
6)

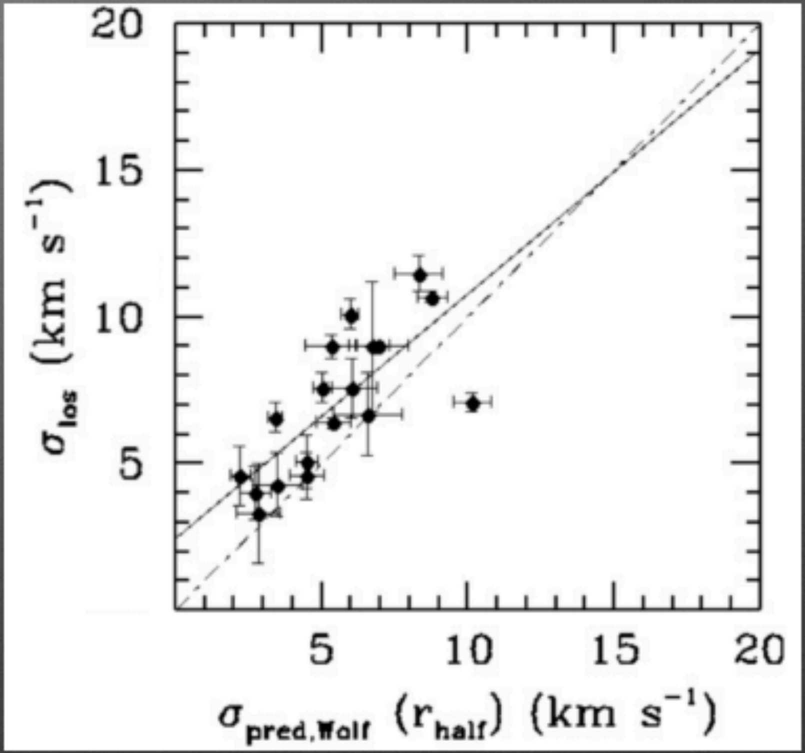


Galactic forces rule dynamics Milky Way dwarf galaxies

Yang Yanbin in Yunnan Sino french meeting Nov 2018

Hammer et al. 2018, ApJ





$$\sigma^2_{los,MW} = \sqrt{2}\, g_{MW}\, r_{half}$$

MW tidal shock predicts

This correlation falsifies the hypothesis of neglecting the MW impact!

NGC1052-DF2 : a Galaxy without DM?

Van Dokkum et al. 2018

➔ **Evidence for DM!** (against modified gravity)

Thank you for your attention!

Merci! Danke!

谢谢！ **どうもありがとう！**