Science with the Hyper Suprime-Cam (HSC) Survey

Rachel Mandelbaum

Survey webpage: http://hsc.mtk.nao.ac.jp/ssp/
Data release 1:
https://hsc-release.mtk.nao.ac.jp/doc/

Subaru Telescope

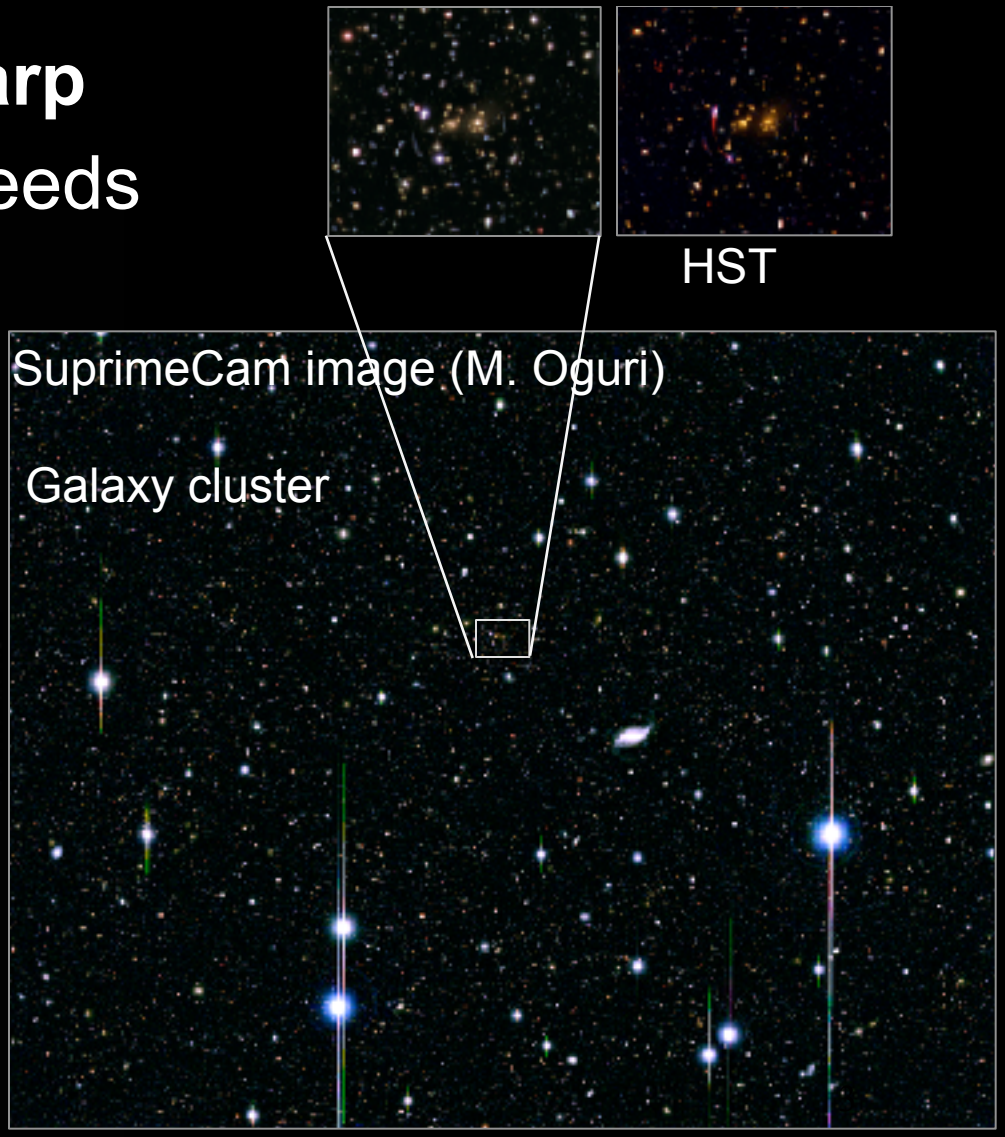
Prime-Focus Instrument

Subaru Telescope

@ summit of Mt. Mauna Kea (4200m), Big Island, Hawaii

Subaru Telescope: wide FoV & excellent image quality

- **Fast, Wide, Deep & Sharp**
- a cosmological survey needs these



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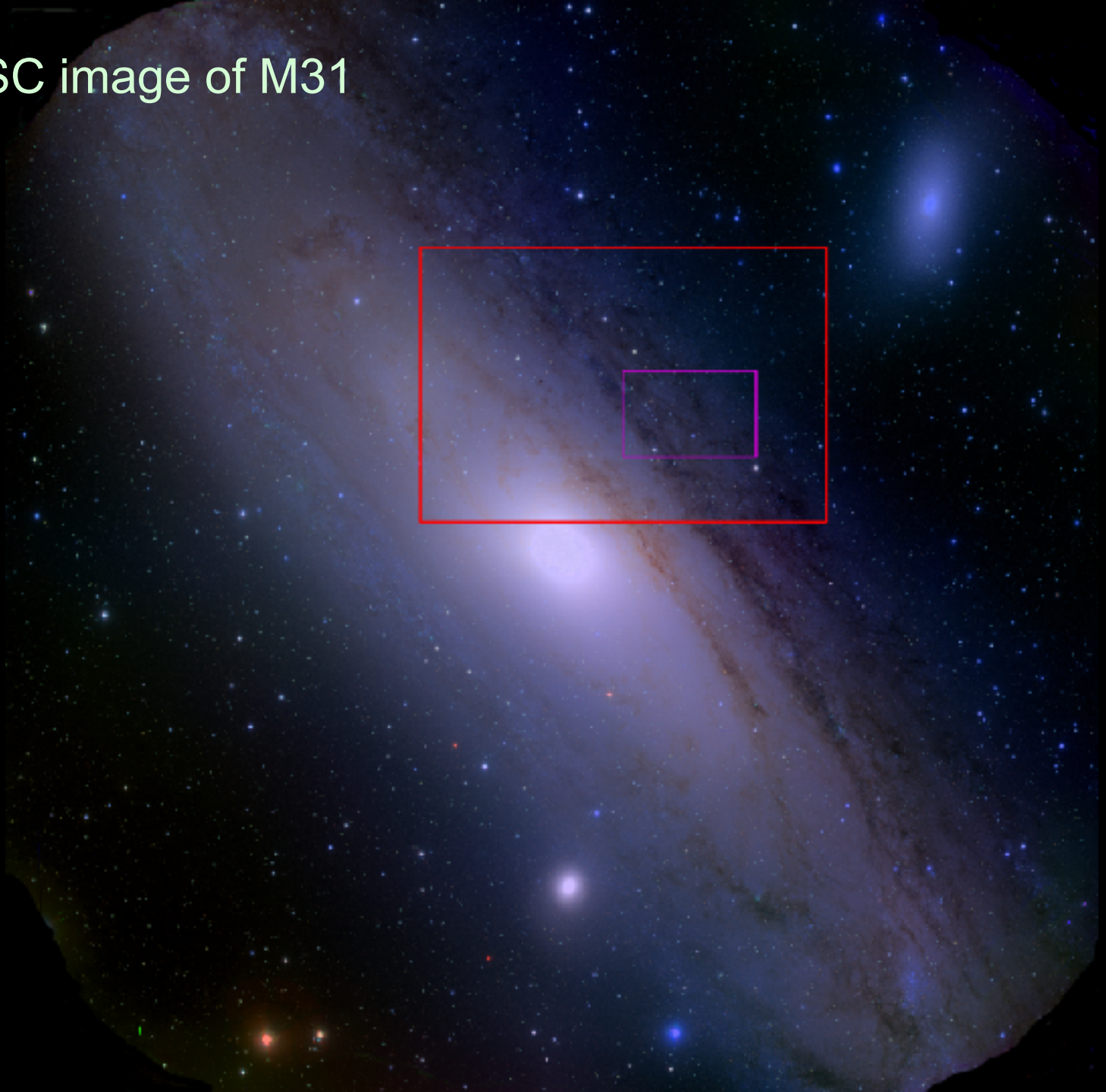
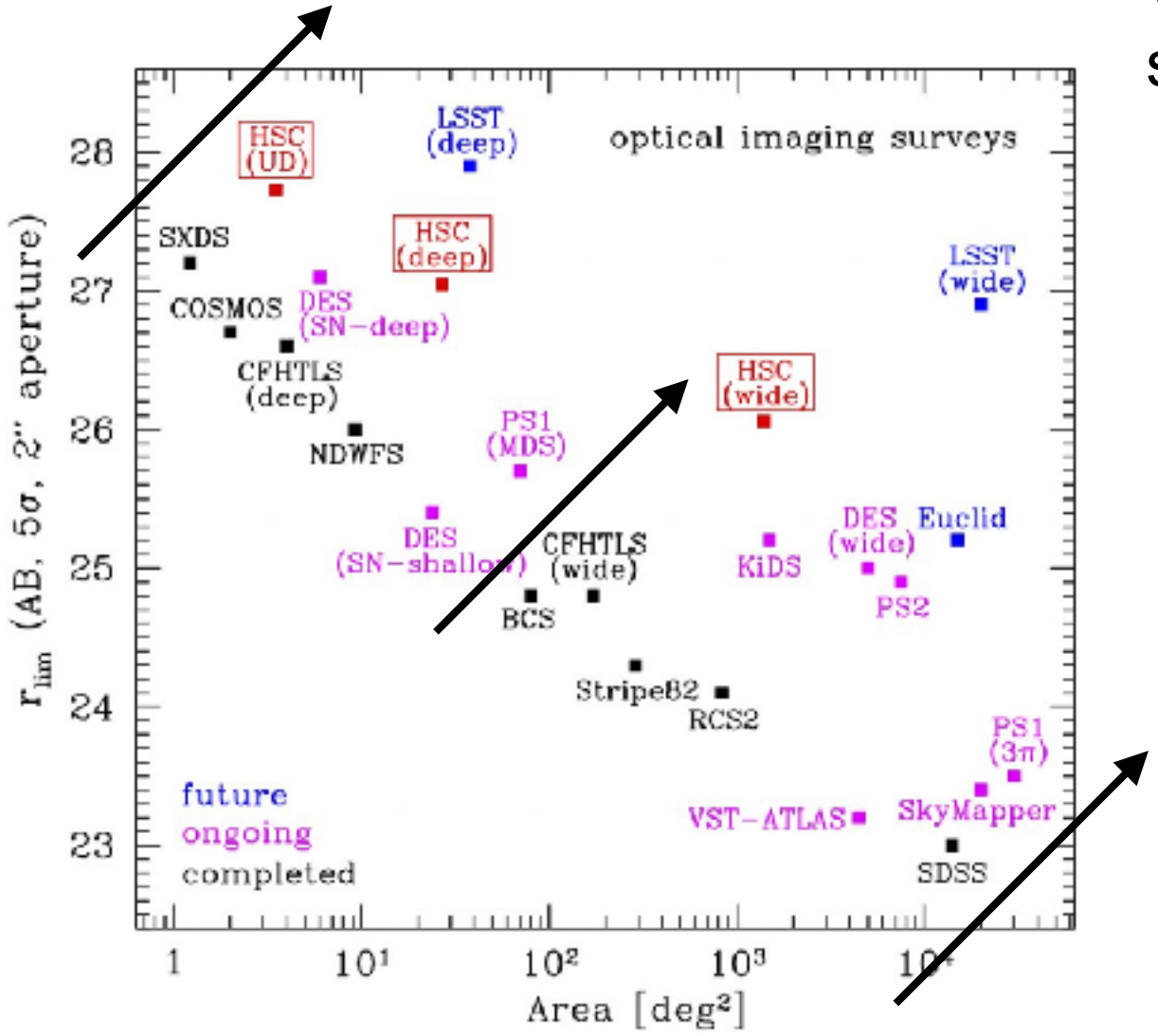
- **Fas**
- a co
these

Hyper Suprime-Cam FoV
1.5 degree diameter

HSC image of M31



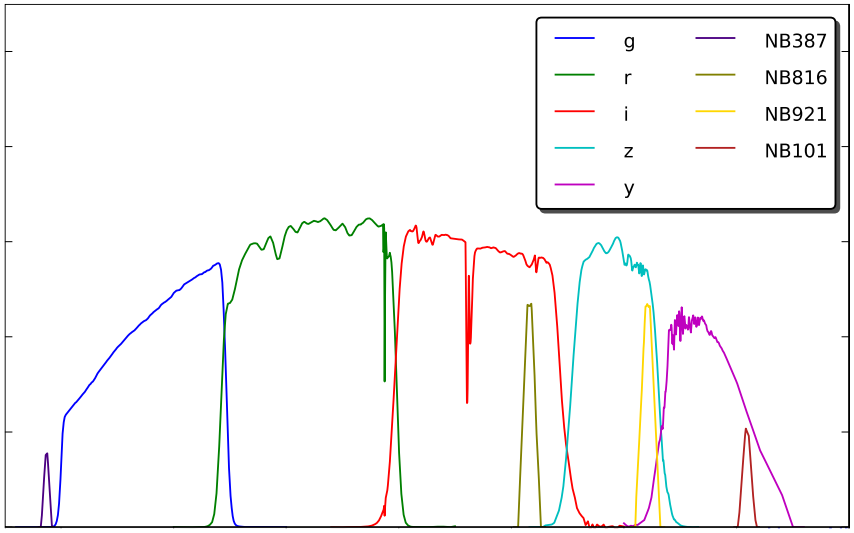
Parameters of HSC SSP Survey



- Wedding-cake-type survey
  - Wide (1400 deg^2, i~26)
  - Deep (28 deg^2, i~27)
  - Ultradeep (3 deg^2, i=27.7)

Filters & Depth

	g	r	i	z	y	N3	N8	N9	N10
W	***10***	***10***	***20***	***20***	***20***	-	-	-	-
D	84	84	126	210	126	84	168	252	-
UD	***420***	***420***	***840***	***1134***	***1134***	-	***630***	***840***	***1050***



For HSC-Deep and Ultra-Deep, a combination of broad- and narrow-band filters enables detection of Lyman-alpha emitters at z=2.2, 5.7, 6.6 and 7.3

HSC Survey started in March 2014

~1.5 nights (S14A), ~12 nights (S14B), ~15 nights in S15A

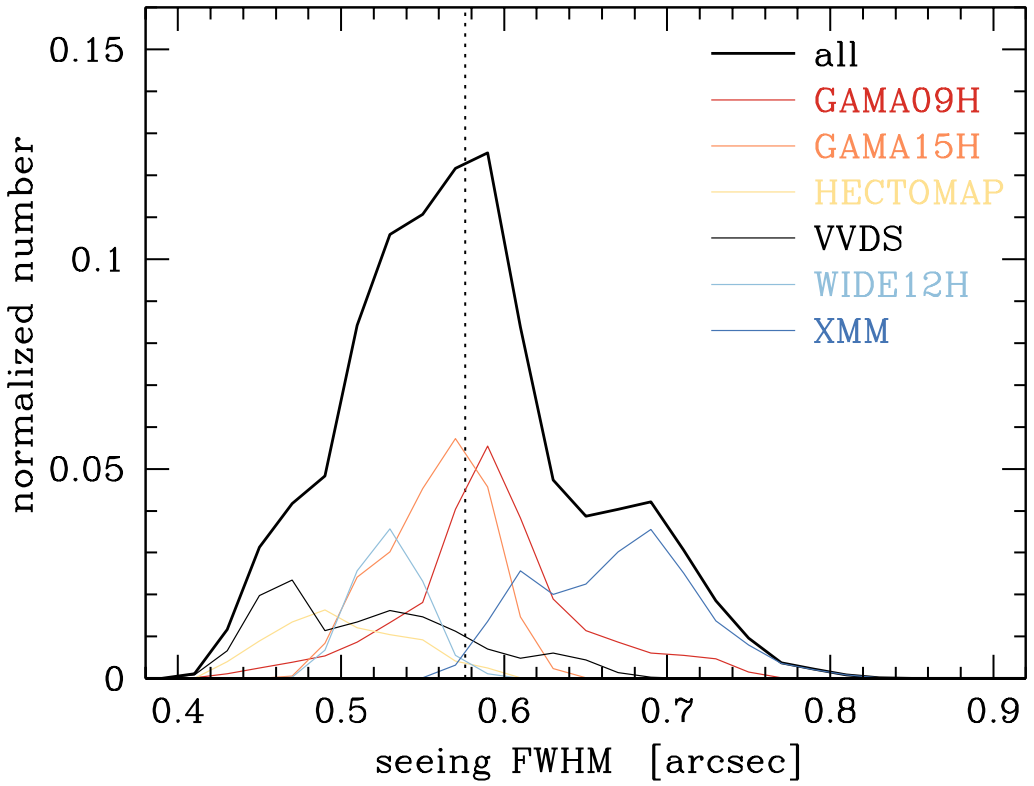
Now (mid-2017) ~50% of the survey's time has been allocated.

Subaru HSC image (riz: ~2.5hrs) COSMOS HST (640 orbits: ~500hrs)

Reduced by HSC pipeline
(Princeton, Kavli IPMU, NAOJ)

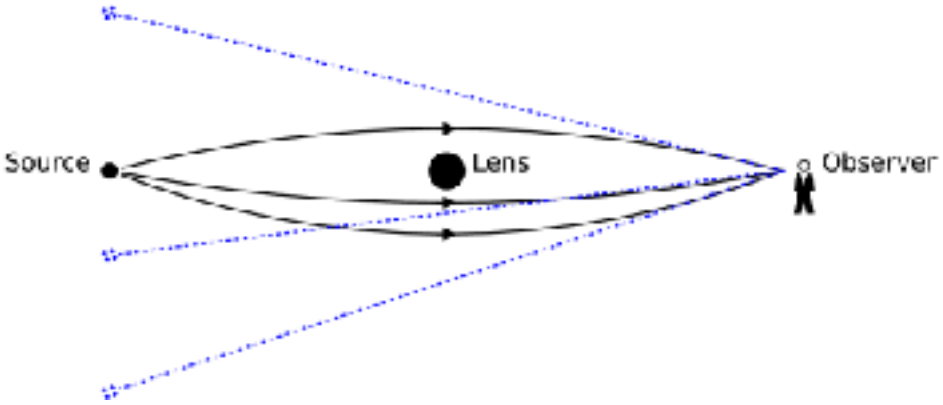
Exquisite image quality

Camera will be presented in Miyazaki+17 in prep



(from RM+17)

Gravitational lensing



Sensitive to all matter along line of sight, including dark matter!

More generally…

Lensing predicted by Newton, with modified predictions by Einstein:

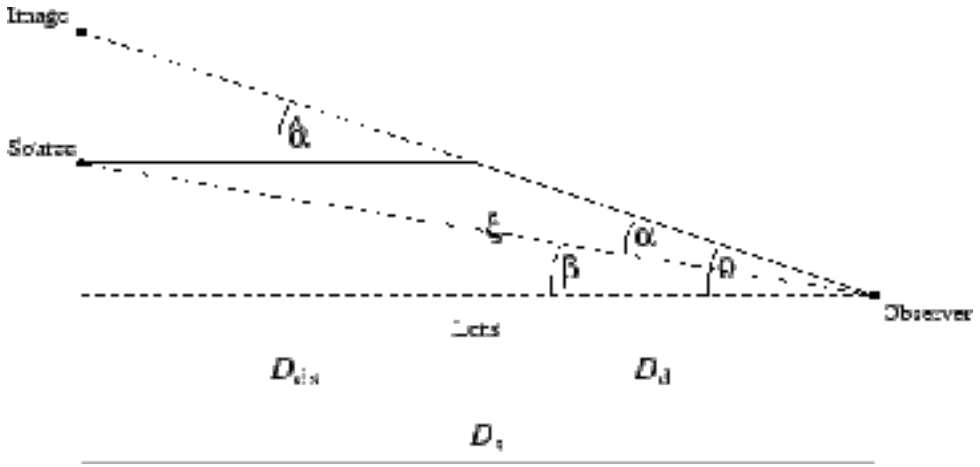
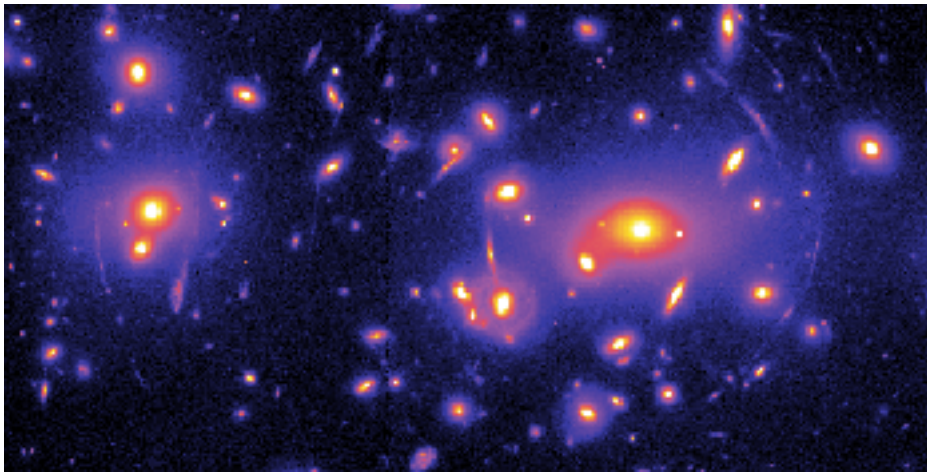


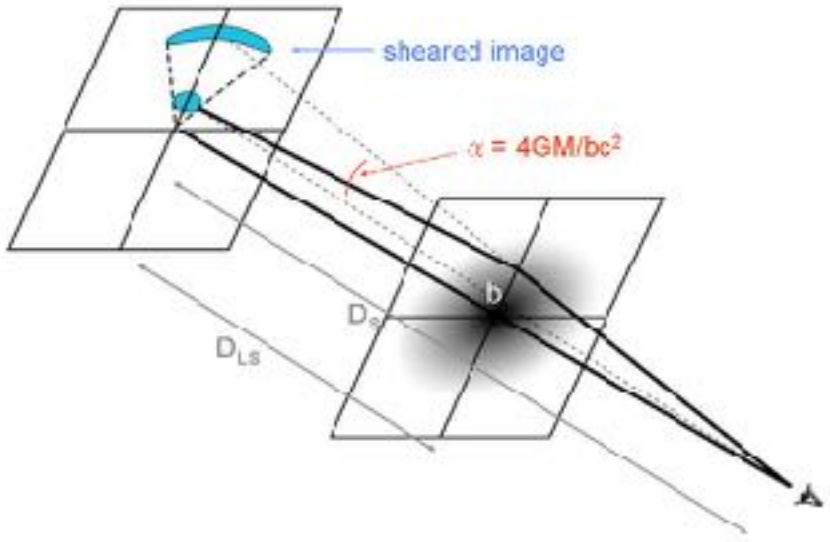
Diagram from Narayan & Bartelmann (1997)

$$\hat{\alpha} = \frac{4G}{c^2}\frac{M(<\xi)}{\xi}$$



Weak lensing

- Very small deflection angles
- Coherent
- Does not require chance superposition like strong lensing



Weak lensing

- Very small deflection angles
- Coherent
- D… …te
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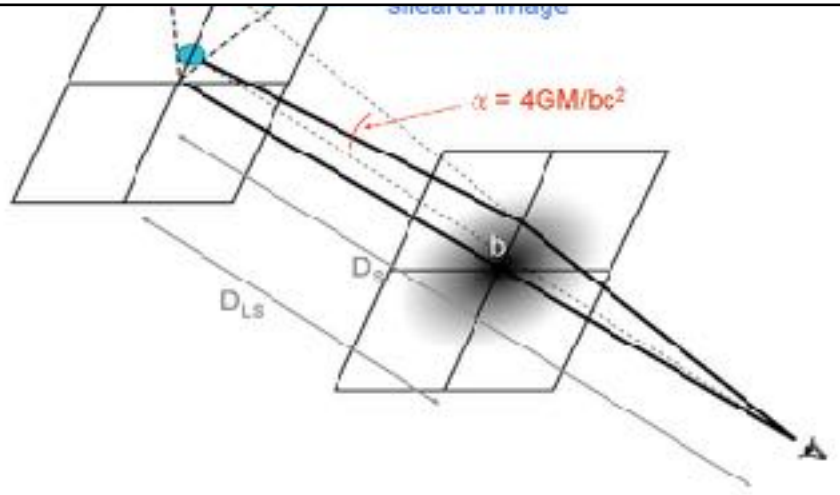
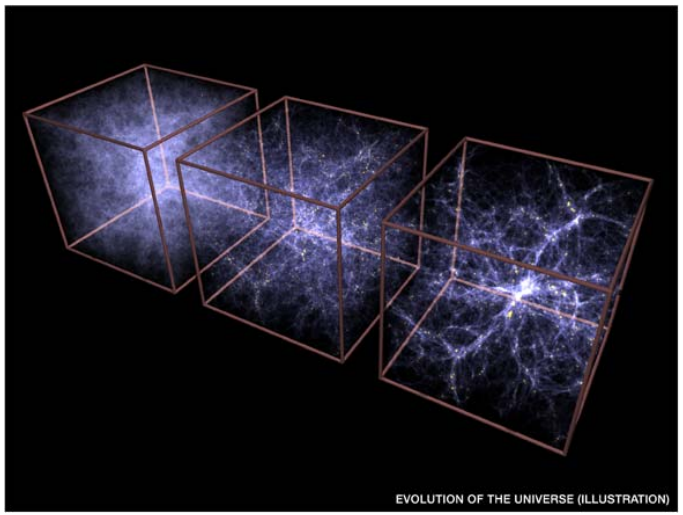
Lensing depends on:
- Enclosed mass
- Distance from that mass
- "Lensing kernel": distances to lens and source

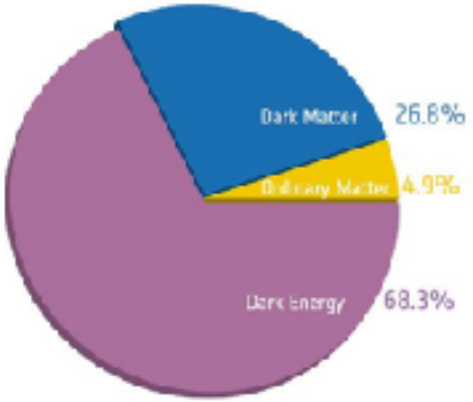


Why should you care about weak lensing?

Structure growth!



Dark matter and dark energy!



ESA/Planck

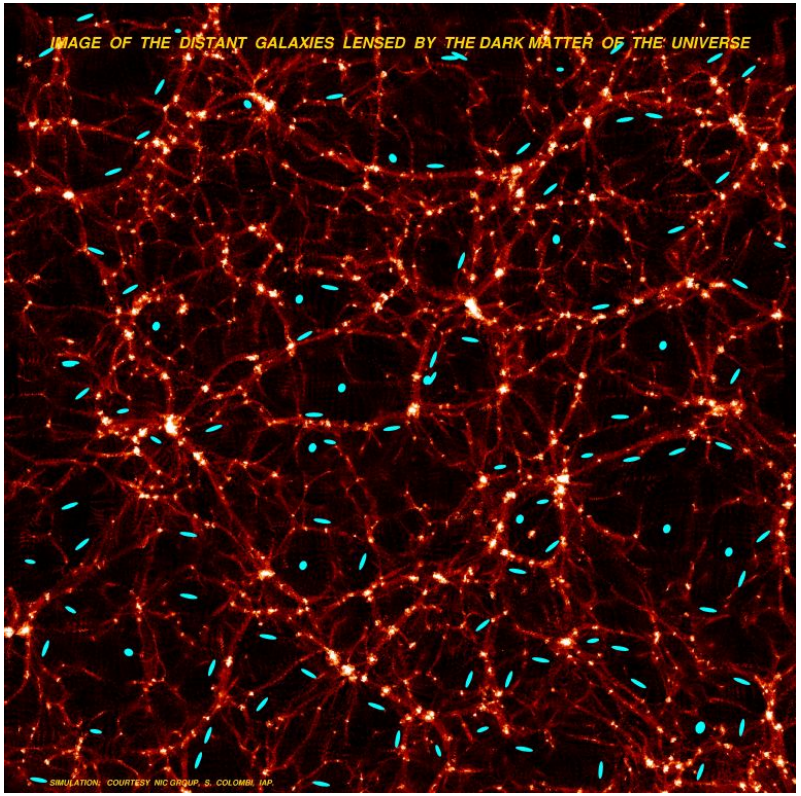
Theory of gravity!

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = 8\pi G T_{\mu\nu}$$

Galaxy-dark matter connection!

So how does this work?

Cosmic shear:
weak lensing by large-scale structure

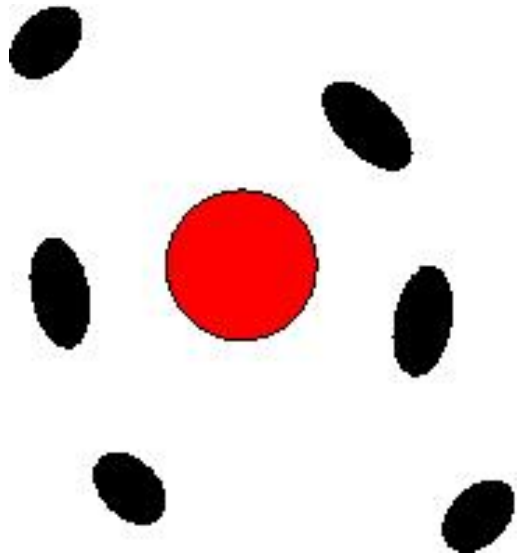


Requires catalogs with:

1. Galaxy positions
2. Galaxy shear estimates

And an estimate of dN/dz.

Another option:
galaxy-galaxy or cluster-galaxy lensing



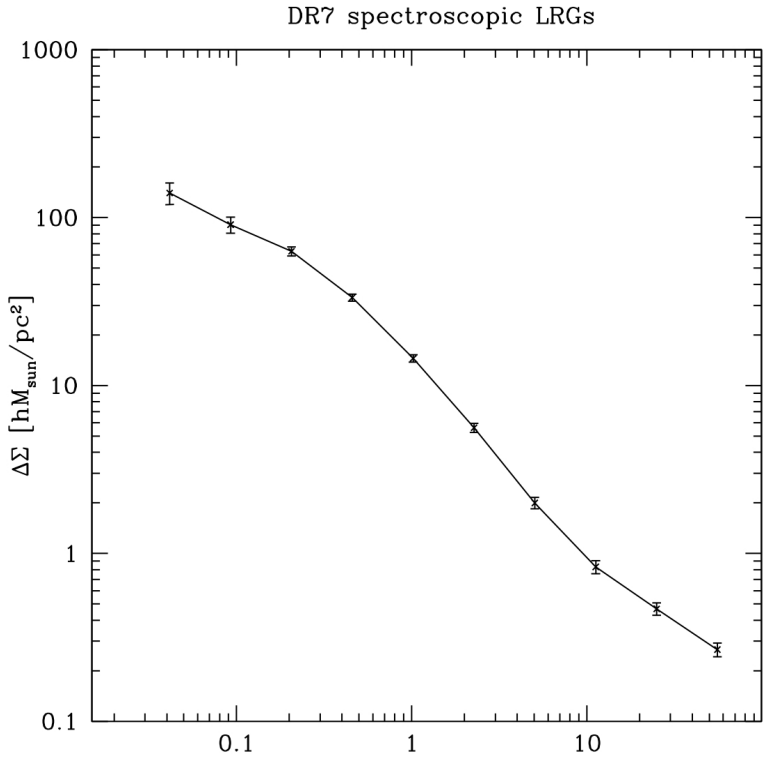
Requires catalogs with:

1. Background galaxy positions, shear estimates, redshift estimates
2. A sample of foreground masses

Another option:

galaxy-galaxy or cluster-galaxy lensing

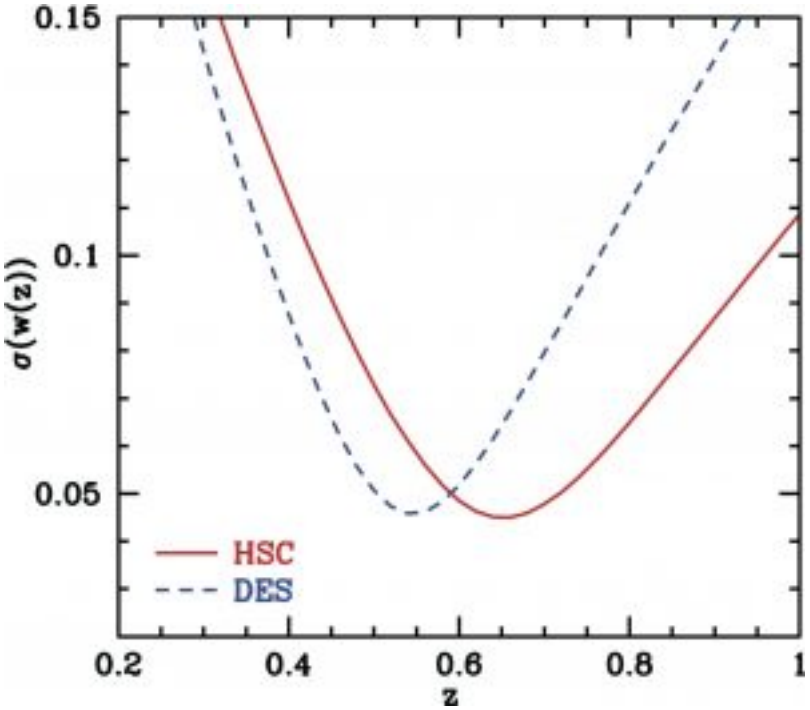
Projected mass



Mass profiles of massive galaxies, including large-scale structure

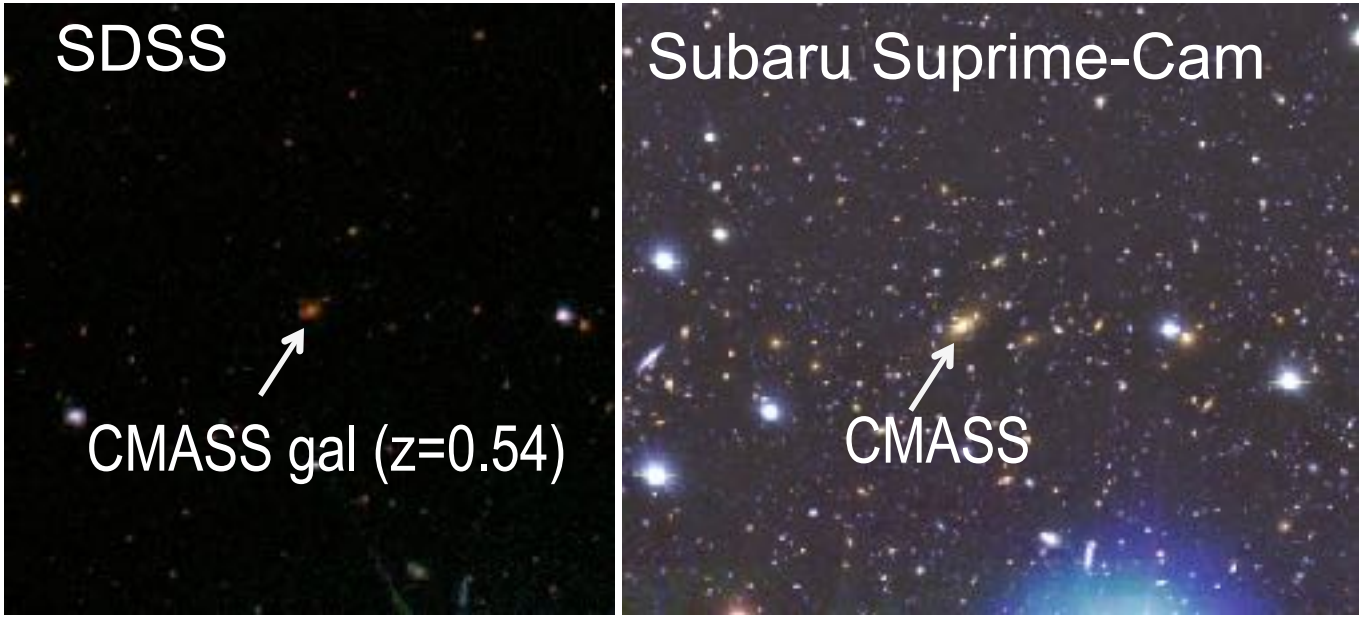
Weak lensing cosmological constraints: dark energy to z=1

Uncertainty in w(z)

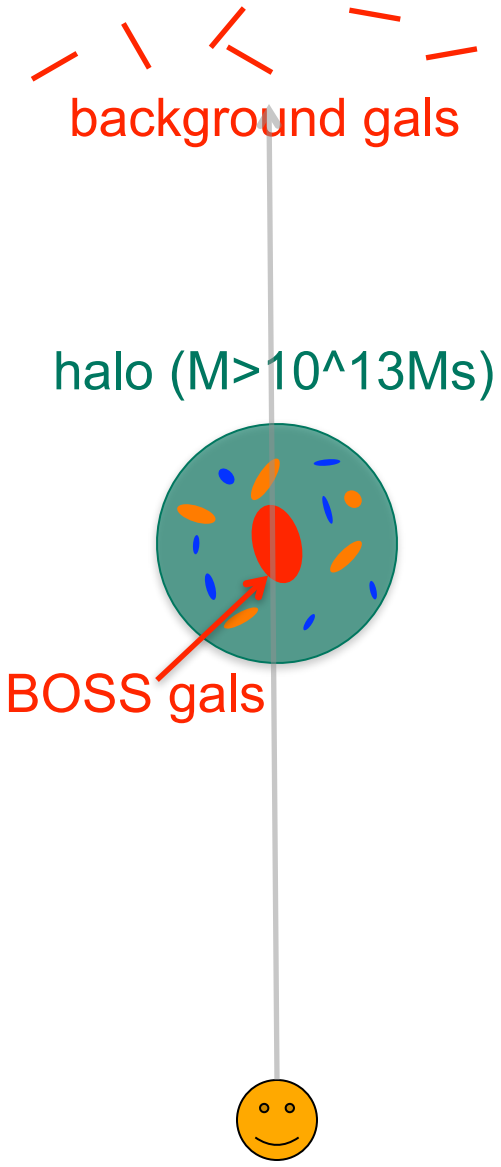


Redshift

Synergy between HSC and BOSS

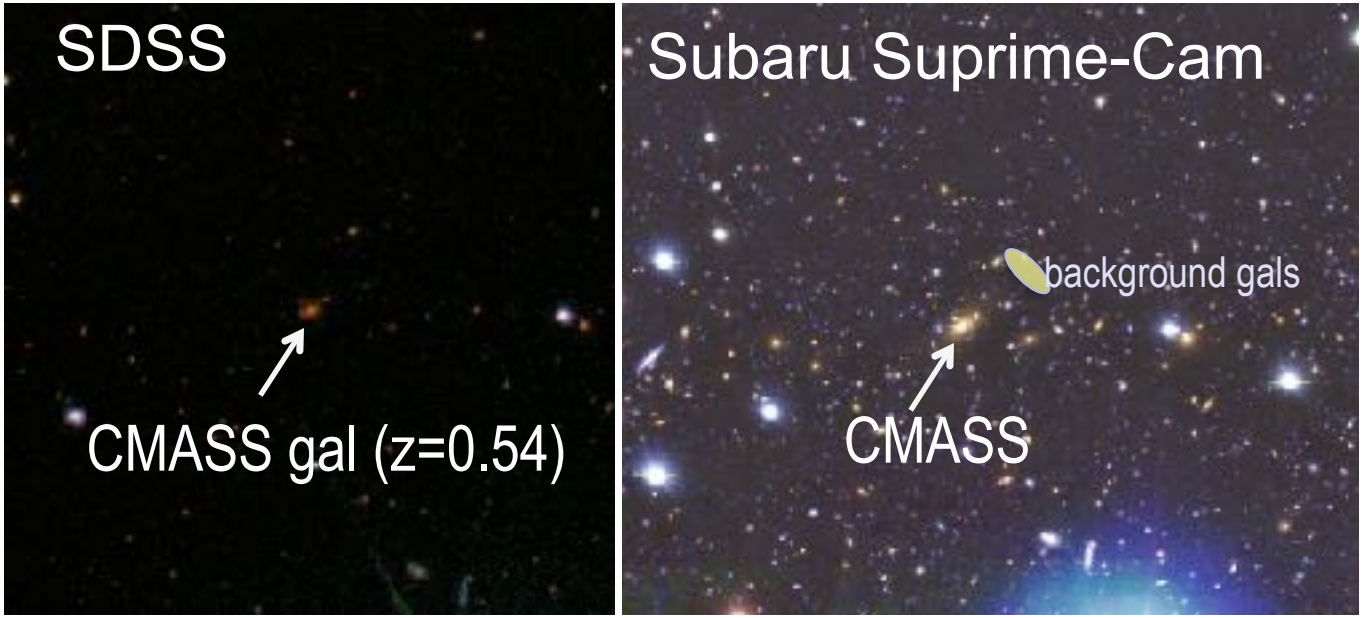


Credit: Masayuki Tanaka (IPMU)

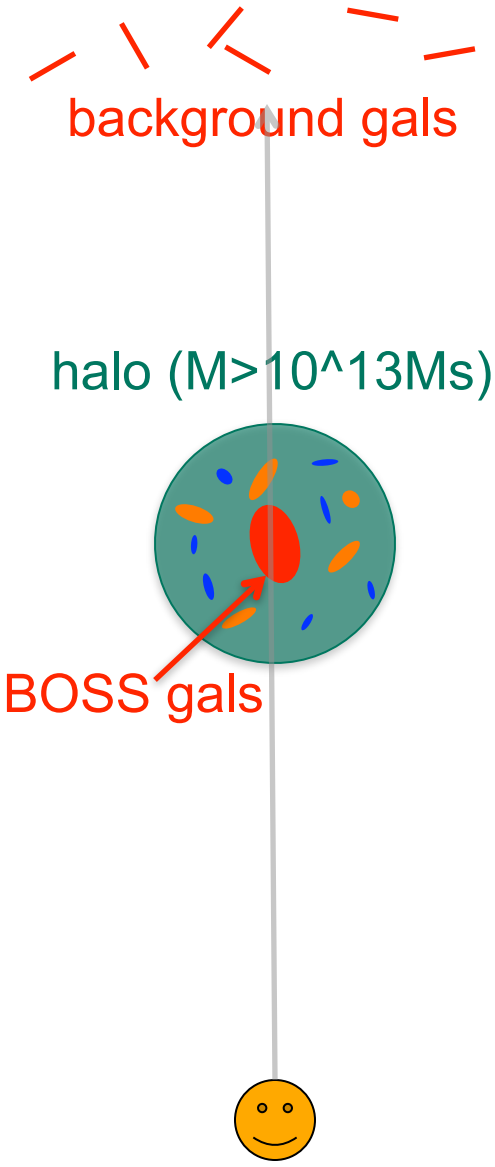


- HSC data will add background galaxies as well as member galaxies around each BOSS galaxy
- Cross-correlation of BOSS with HSC galaxies (shapes and positions) over 1400 sq. degrees

Synergy between HSC and BOSS



Credit: Masayuki Tanaka (IPMU)



- HSC data will add background galaxies as well as member galaxies around each BOSS galaxy
- Cross-correlation of BOSS with HSC galaxies (shapes and positions) over 1400 sq. degrees

HSC data release in Feb 2017

- Includes a wide range of image and catalog-level products, sky map, ...
- ~100 deg^2 of data in all 5 bands to full depth
- Some deep-layer data released as well
- Some more data products in incremental releases as time goes on (e.g., early June, …)

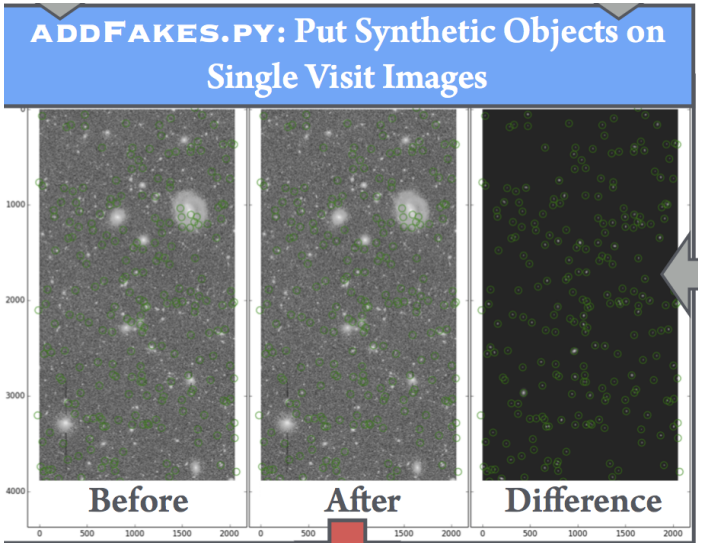
Quick snapshots of some results so far

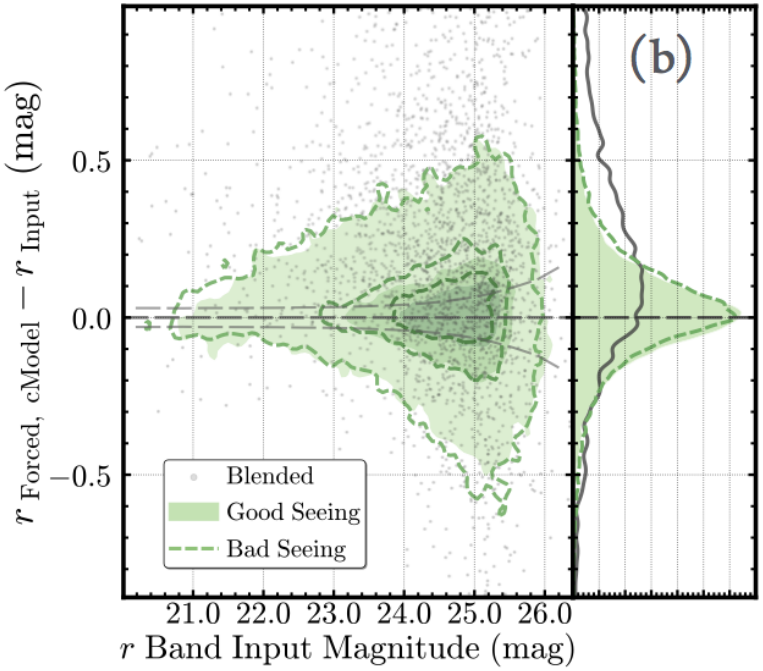
Characterization and Photometric Performance of the Hyper Suprime-Cam Software Pipeline

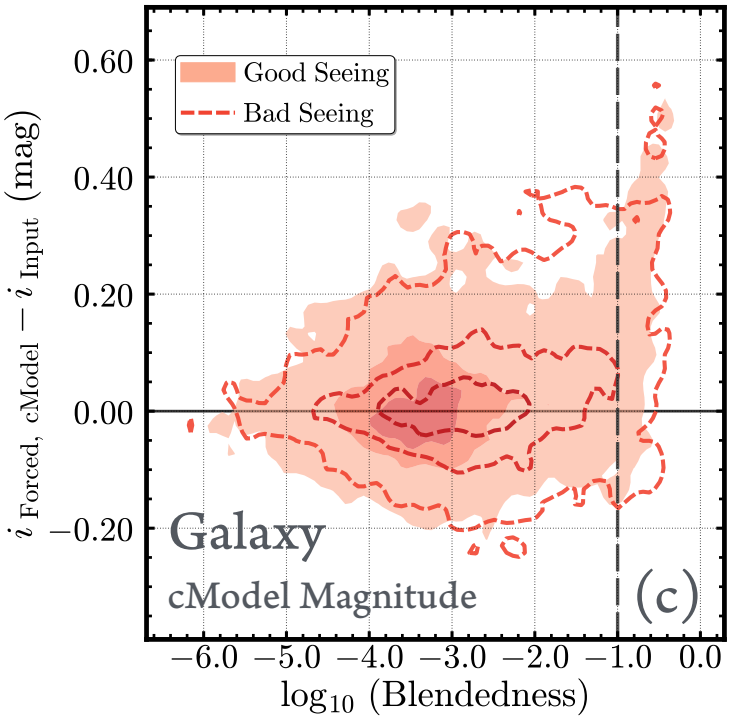
Song Huang [1,2] Alexie Leauthaud [1,2], Ryoma Murata [2, 4], James Bosch [3], Paul Price [3], Robert Lupton [3], Rachel Mandelbaum [5], Claire Lackner [2], Steven Bickerton [2], Satoshi Miyazaki [6,7], Jean Coupon [8], Masayuki Tanaka [6]

arxiv:1705.01599

Note software pipeline is described in Bosch et al (2017, arxiv:1705.06766)





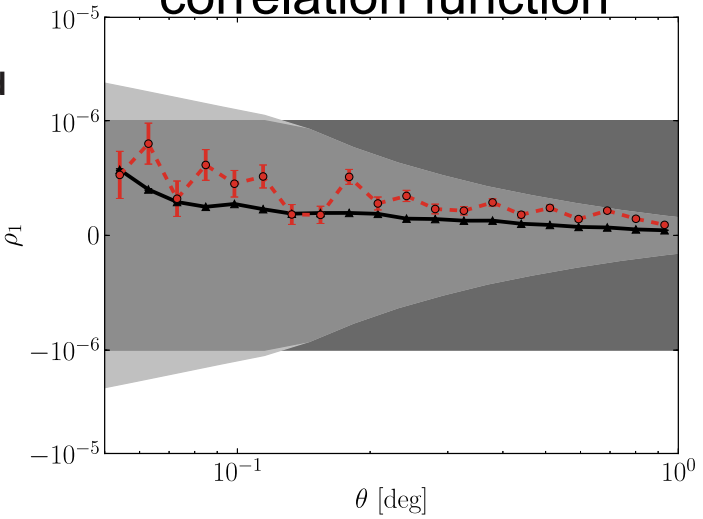


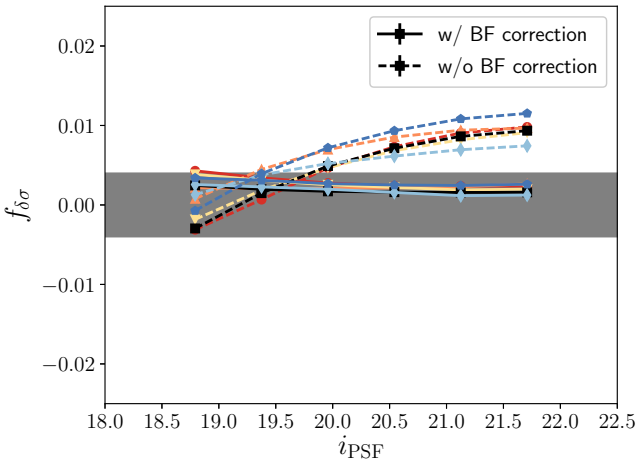
The first-year shear catalog of the Subaru Hyper Suprime-Cam SSP Survey

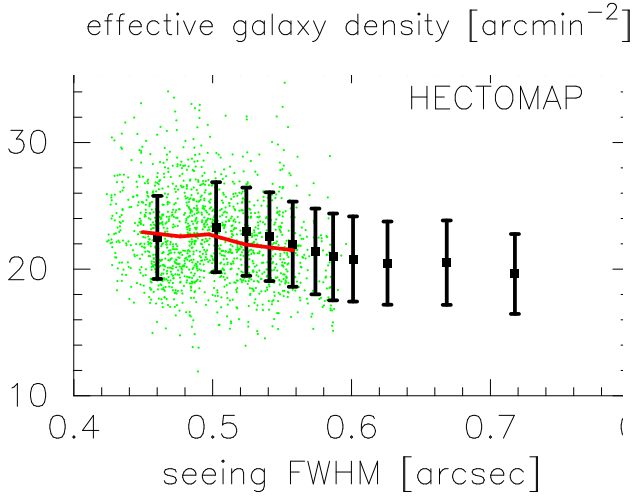
Rachel Mandelbaum[1], Hironao Miyatake[2,3], Takashi Hamana[4], Masamune Oguri[5,6,3], Melanie Simet[7,2], Robert Armstrong[8], James Bosch[8], Ryoma Murata[3,6], François Lanusse[1], Alexie Leauthaud[9], Jean Coupon[10], Surhud More[3], Masahiro Takada[3], Satoshi Miyazaki[4], Joshua S. Speagle[11], Masato Shirasaki[4], Cristóbal Sifón[8], Song Huang[3,9], Atsushi J. Nishizawa[12], Elinor Medezinski[8], Yuki Okura[13,14], Nobuhiro Okabe[15,16], Nicole Czakon[17], Ryuichi Takahashi[18], Will Coulton[19], Chiaki Hikage[3], Yutaka Komiyama[4,20], Robert H. Lupton[8], Michael A. Strauss[8], Masayuki Tanaka[4] and Yousuke Utsumi[16]

arxiv:1705.06745

PSF shape residual correlation function





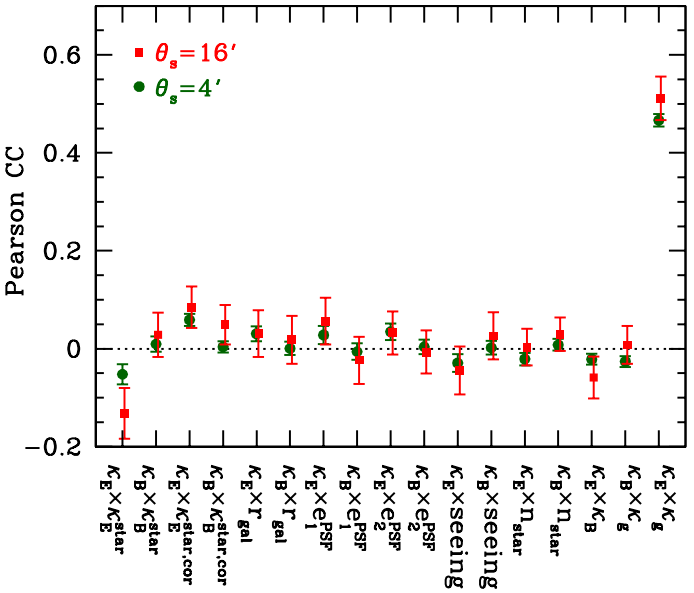


Empirical constraints on PSF modeling errors and the importance of brighter/fatter corrections.

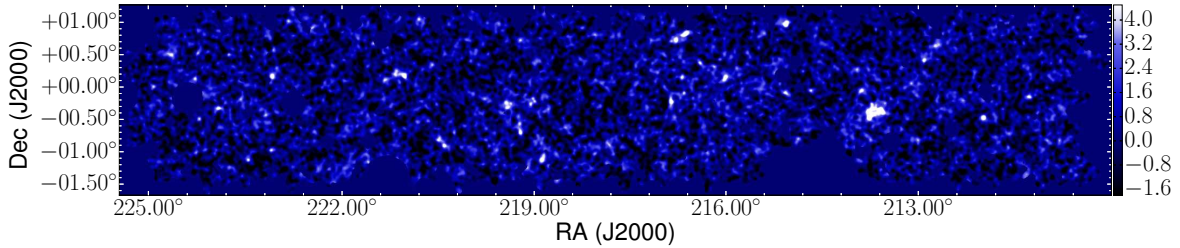
Two- and three-dimensional wide-field weak lensing mass maps from the Hyper Suprime-Cam Subaru Strategic Program S16A data

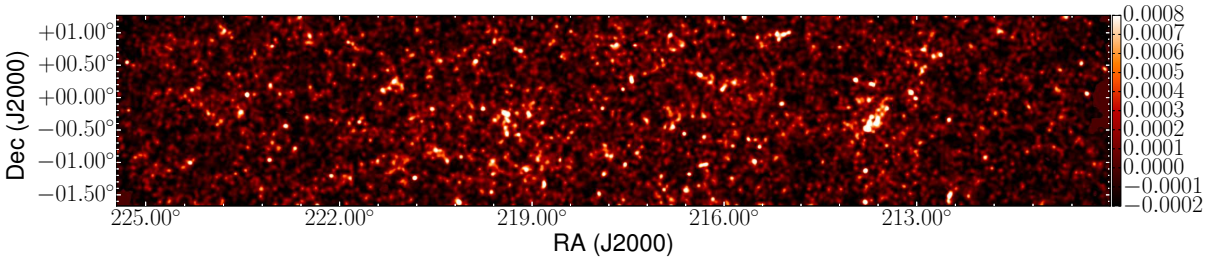
Masamune OGURI[1,2,3], Satoshi MIYAZAKI[4,5], Chiaki HIKAGE[3], Rachel MANDELBAUM[6], Yousuke UTSUMI[7], Hironao MIYATAKE[8,3], Masahiro TAKADA[3], Robert ARMSTRONG[9], James BOSCH[9], Yutaka KOMIYAMA[4,5], Alexie LEAUTHAUD[10], Surhud MORE[3], Atsushi J. NISHIZAWA[11] and Nobuhiro OKABE[7,12,13]

arxiv:1705.06792



Total mass from lensing



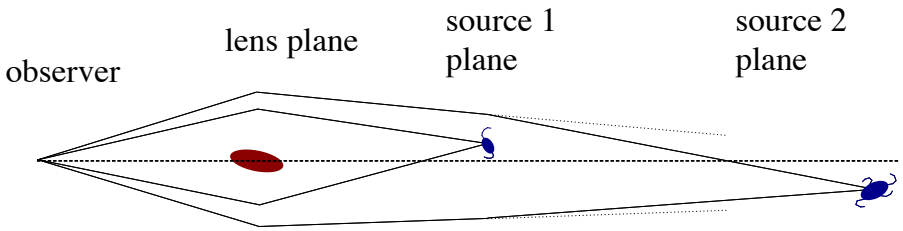


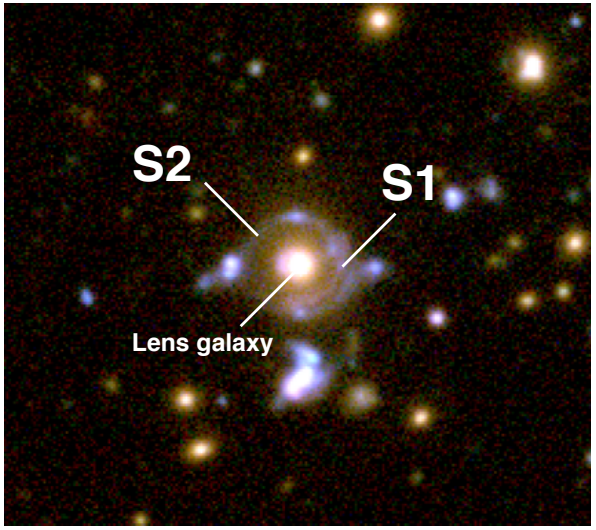
Stellar mass of LRGs

Mass map systematics tests

Strong lensing

Very rare double source plane systems



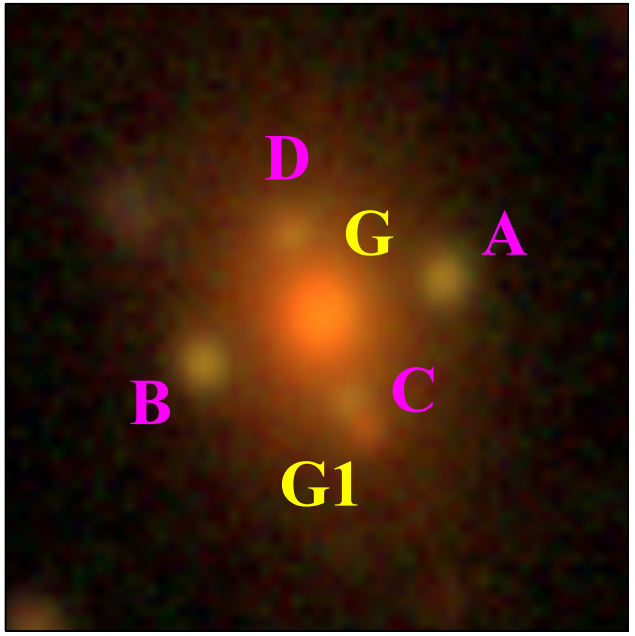


$z_{LENS} = 0.795$

$z_{S1} = 1.30$

$z_{S2} = 1.99$

"The Eye of Horus" (Tanaka, Wong, A. More et al 2016)



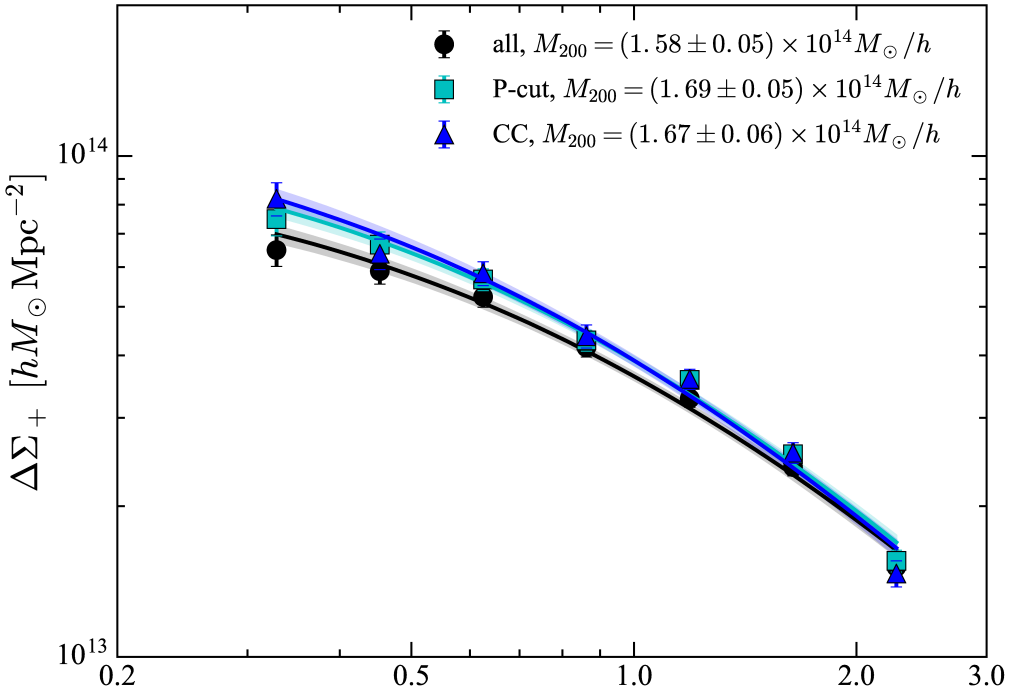
Quadruply lensed AGN! (More et al 2016)

z_{QSO}=3.8

Source Selection for Cluster Weak Lensing Measurements in the Hyper Suprime-Cam Survey

Elinor Medezinski[1], Masamune Oguri[2,3,4], Atsushi J. Nishizawa[5], Joshua S. Speagle[6], Hironao Miyatake[2,7], Keiichi Umetsu[8], Alexie Leauthaud[9], Ryoma Murata[2,4], Rachel Mandelbaum[10], Cristóbal Sifón[1], Michael A. Strauss[1], Song Huang[2,9], Melanie Simet[7,11], Nobuhiro Okabe[12,13], Masayuki Tanaka[14] and Yutaka Komiyama[14,15]

arxiv:1706.00427



Robust source selection for lensing measurements by optically-selected cluster samples (very high S/N)

Advertisement of ongoing work

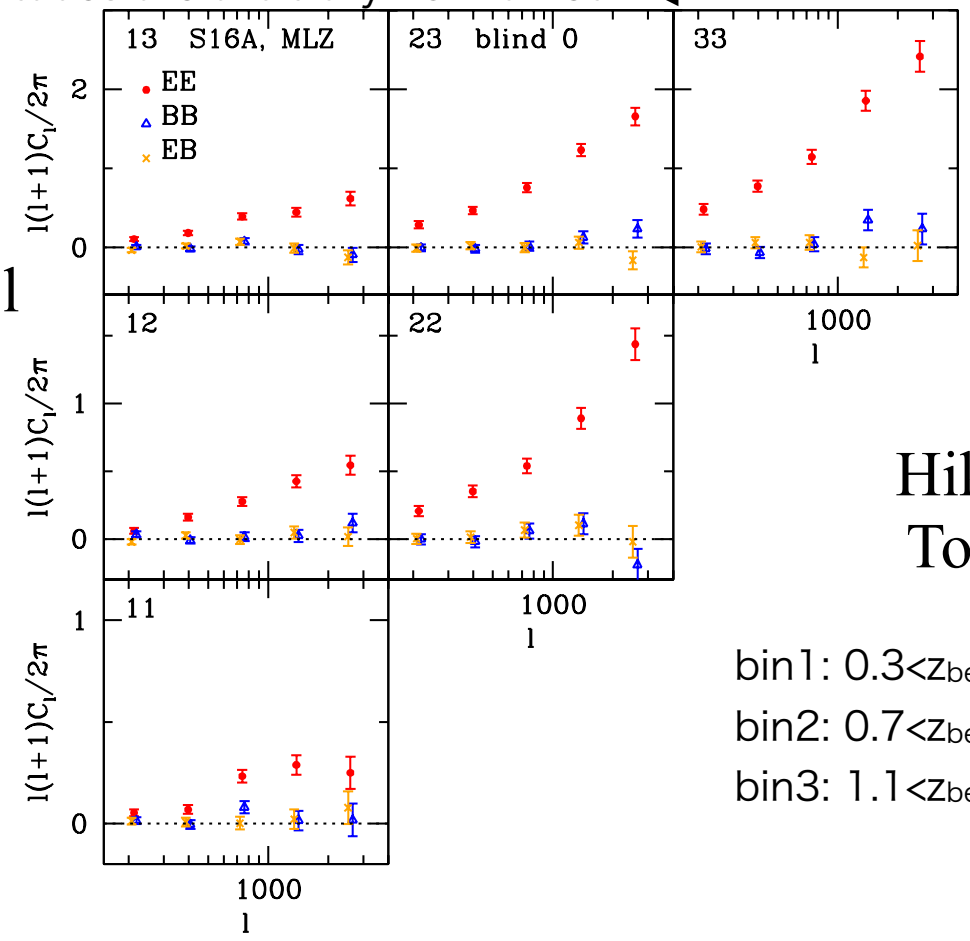
Cosmic shear tomography

(cross-correlations of shear in redshift slices)

Part of our blinding scheme for cosmology analysis

amplitudes are arbitrary normalized

Power at wavenumber l



To appear in Hikage et al (in prep); Total S/N exceeds 20

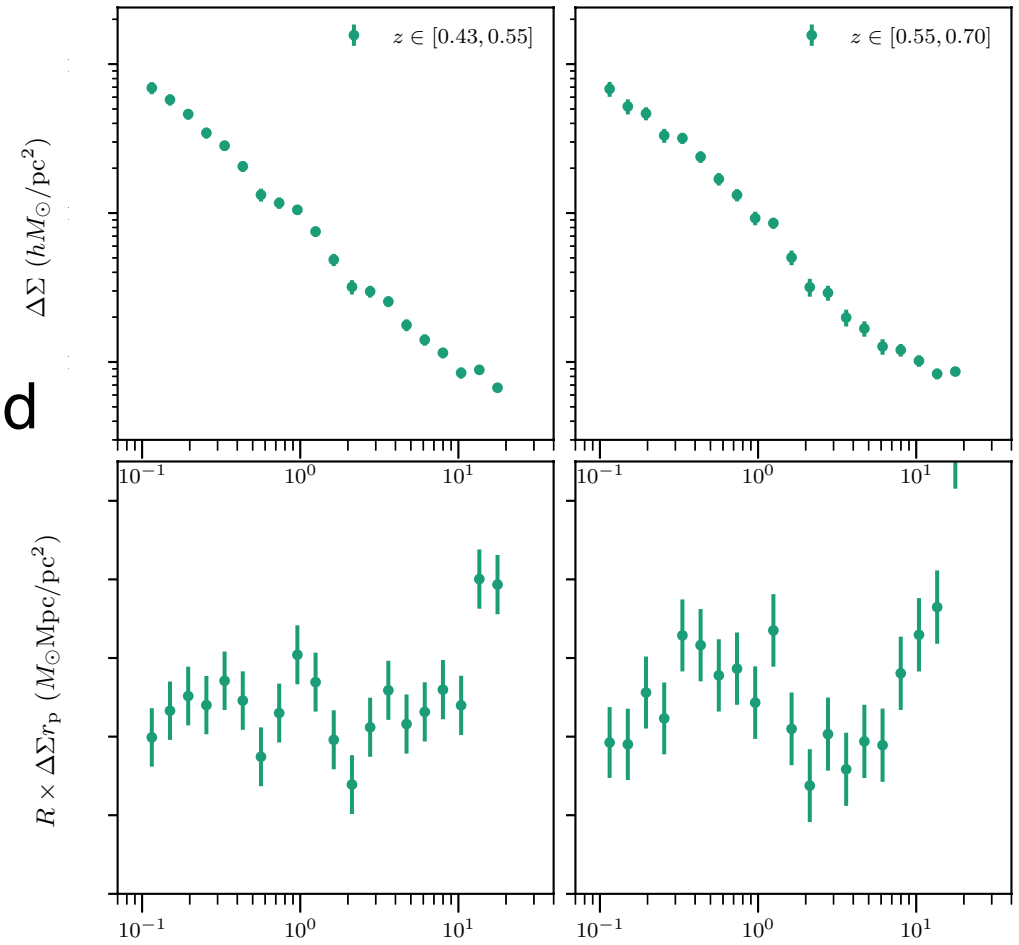
bin1: $0.3<z_{best}<0.7$

bin2: $0.7<z_{best}<1.1$

bin3: $1.1<z_{best}<1.5$

Lensing of SDSS-III BOSS CMASS galaxies

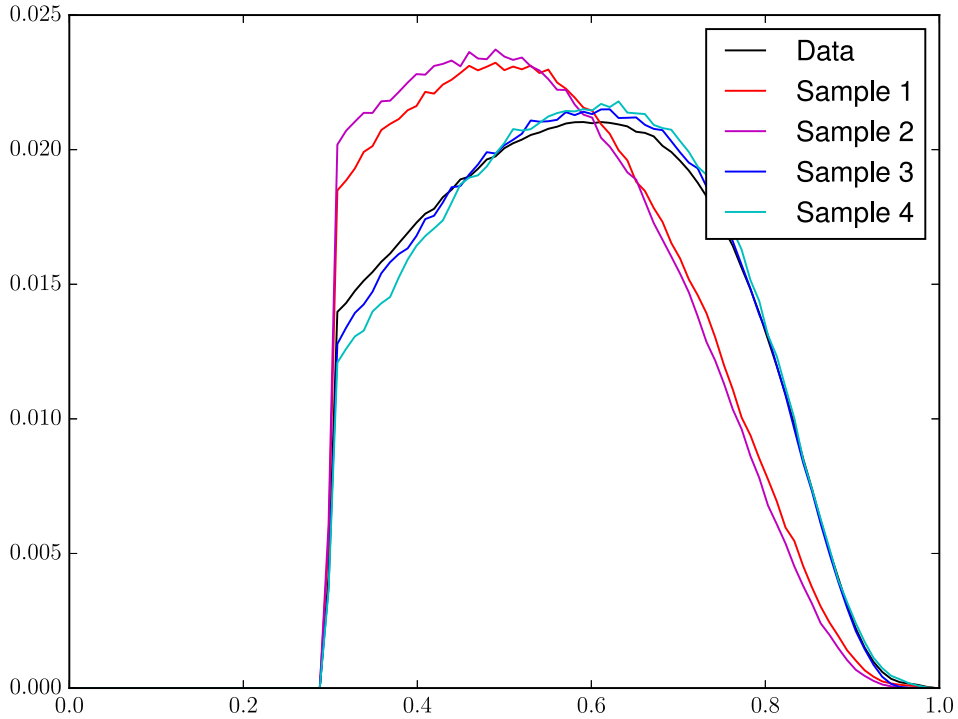
Projected mass



Measurement courtesy of Surhud More

(No amplitudes shown due to use of blinded analysis method; random vertical offset applied)

Validating weak lensing analysis with simulations



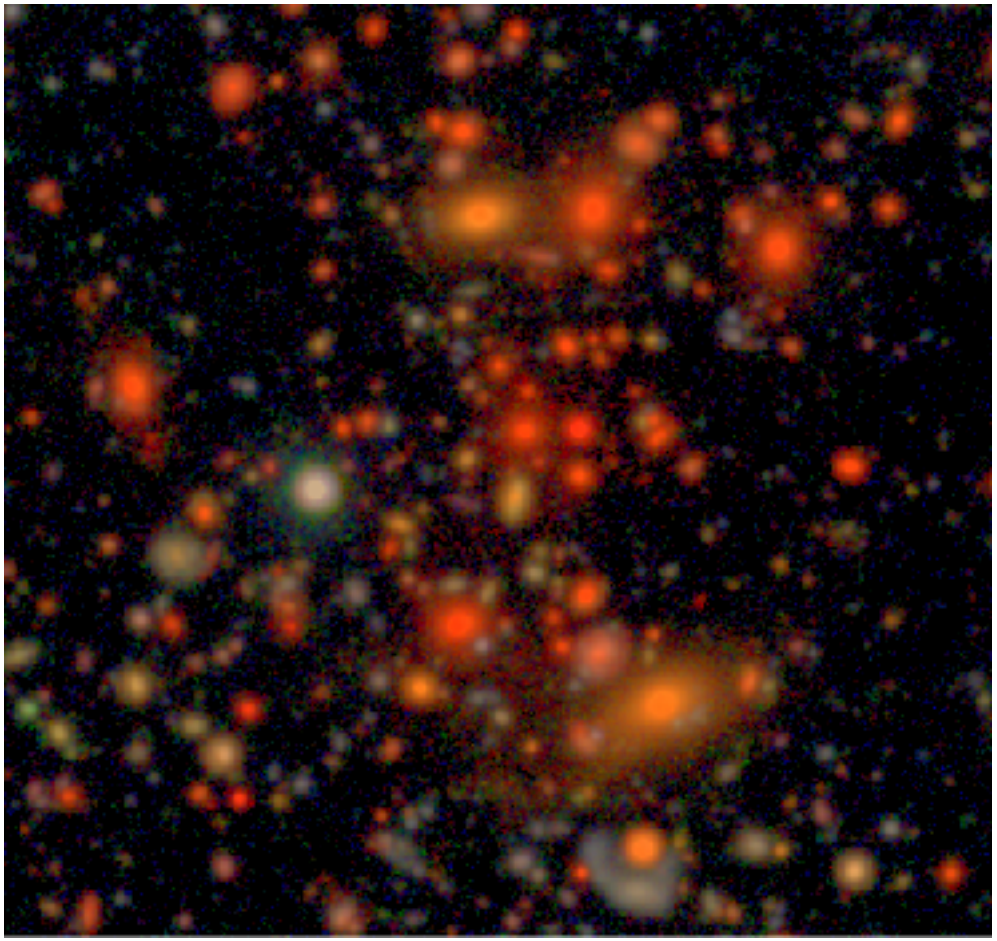
Apparent size compared to PSF

How you define your input galaxy sample matters!

Simulations can reproduce observed galaxy properties if we include contributions from neighboring objects (instead of just isolated galaxies)

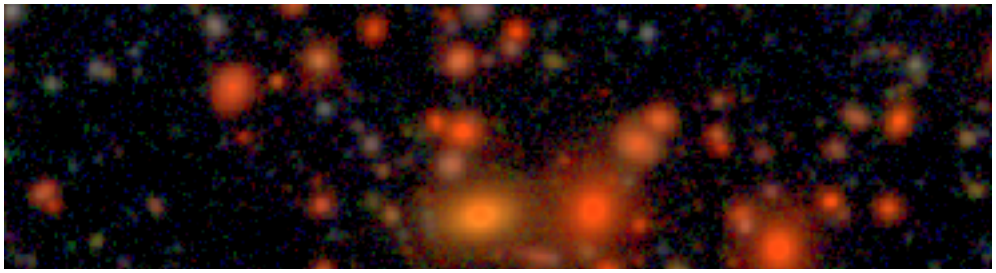
Mandelbaum et al (in prep)

Looking forward

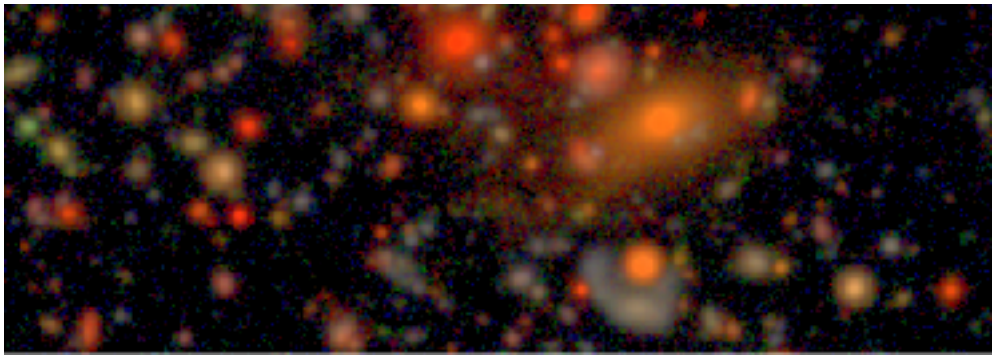


it's ~~turtles~~ galaxies all the way down

Looking forward



Blending is a major challenge for deep future surveys like LSST, and will affect all aspects of the analysis (photometric redshifts, shear, …). We need to confront this problem and its impact on cosmological analysis.



Summary

- The HSC survey had its first data release
  - You should download and play with our beautiful data! Check out hscMap
- Lots of science is being done!
  - Keep an eye on arxiv
- We are learning valuable lessons for the era of precision cosmology.
- Feel free to e-mail me any questions: rmandelb@andrew.cmu.edu