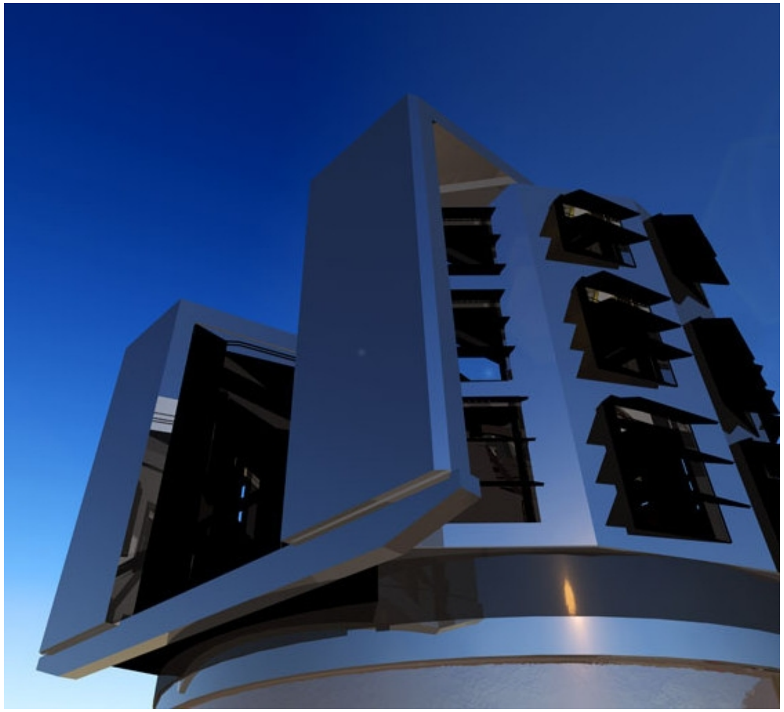
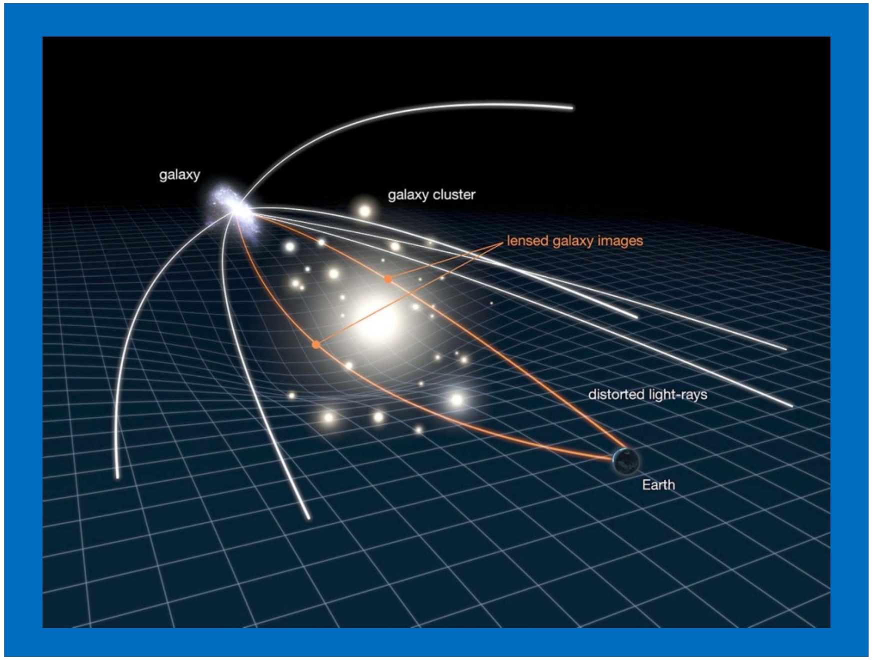
Measuring intrinsic alignments using multiple shear estimates

In collaboration with Rachel Mandelbaum





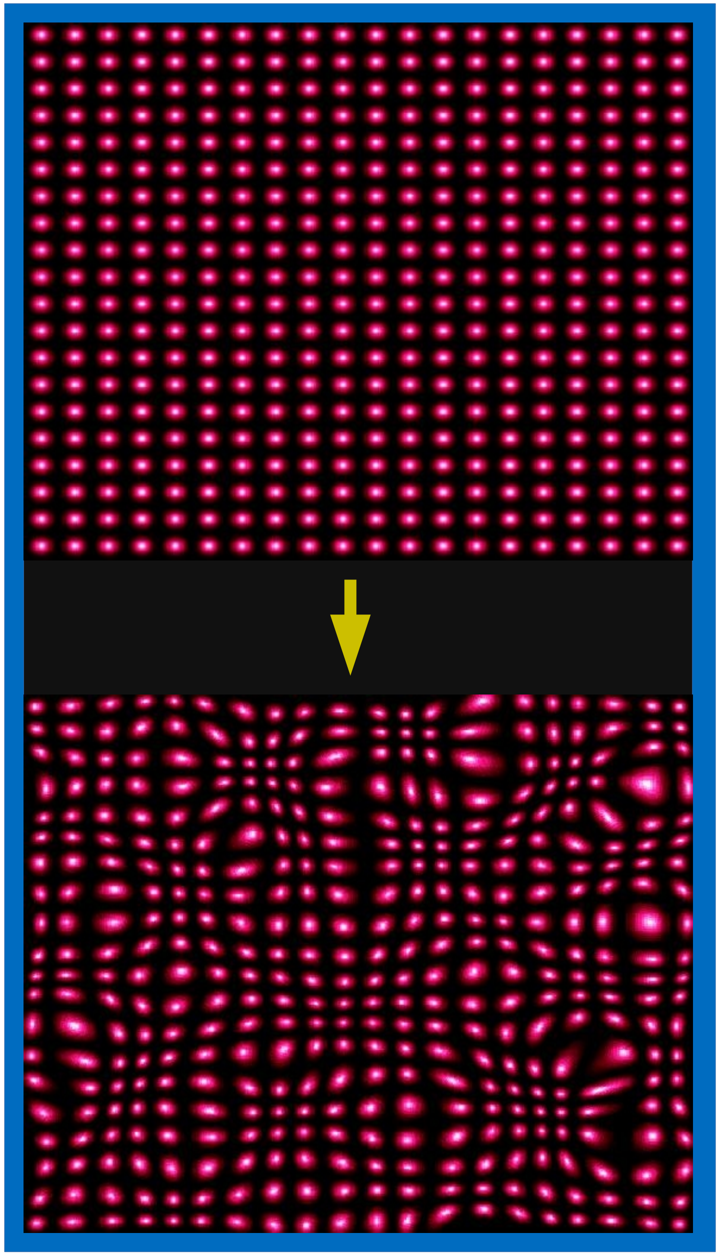
Images: cfhtlens.org; http://www.lsst.org/

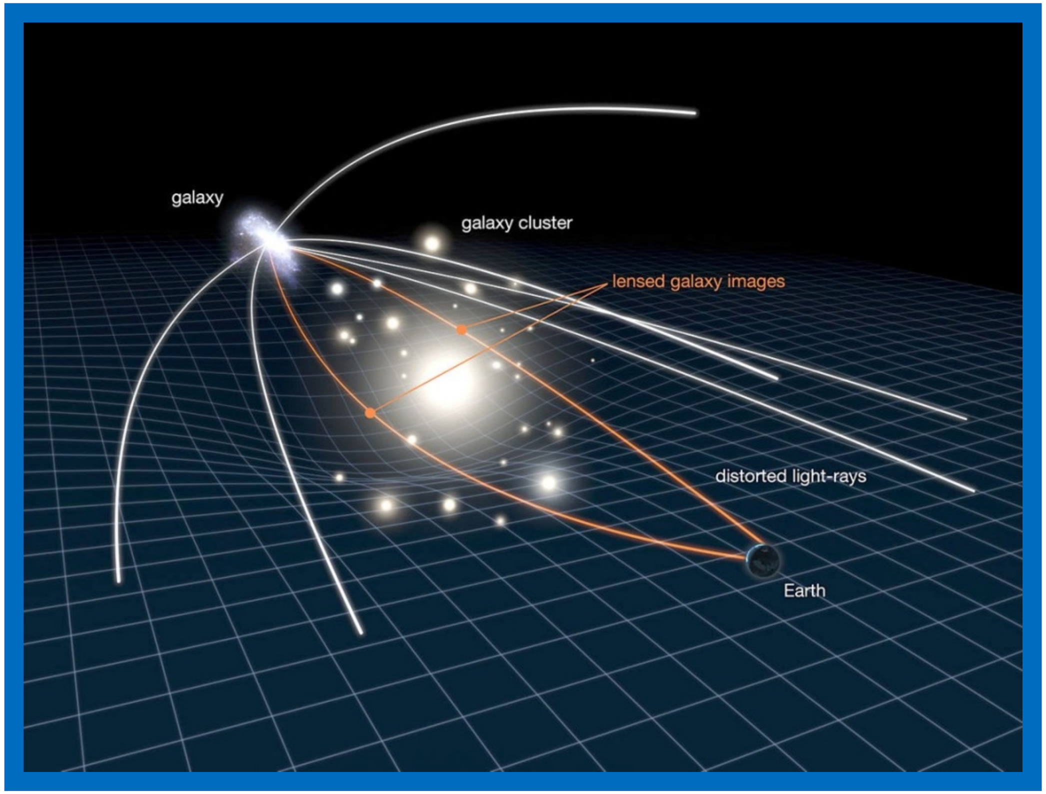
Danielle Leonard
McWilliams Center for Cosmology,
Carnegie Mellon University
danielll@andrew.cmu.edu
February 12, 2018

Outline

- Background and motivation
- A new method for measuring IA
- Forecasting method performance
- Conclusions

Weak gravitational lensing





Images: http://gravitationallensing.pbworks.com, cfhtlens.org

Intrinsic alignment of galaxies

To extract cosmological information from weak lensing observations, we need to account for local gravitational effects.

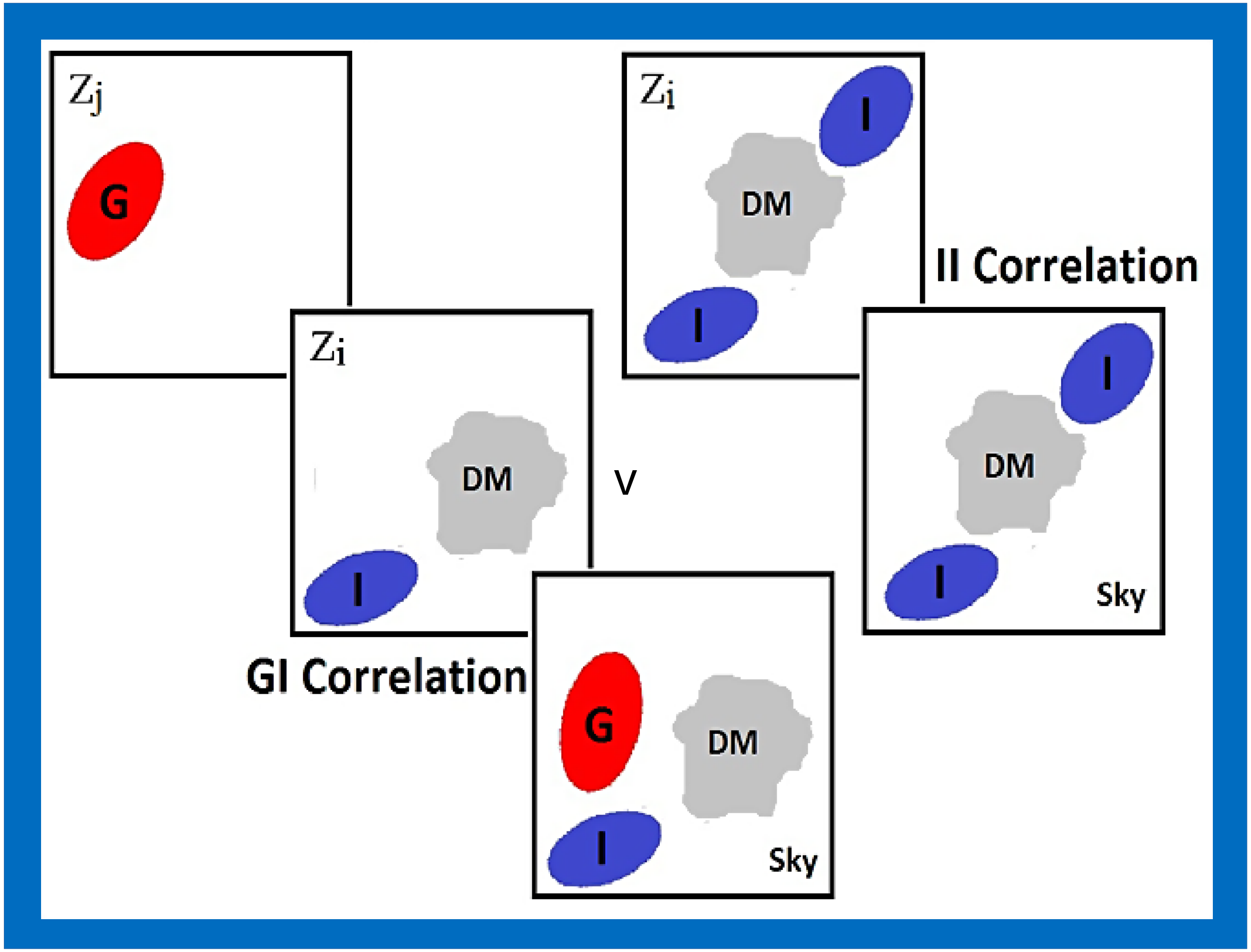


Image: Troxel & Ishak 2012, 1203.2138

Intrinsic alignment of galaxies

Contamination to galaxy-galaxy lensing (due to photo-z's):

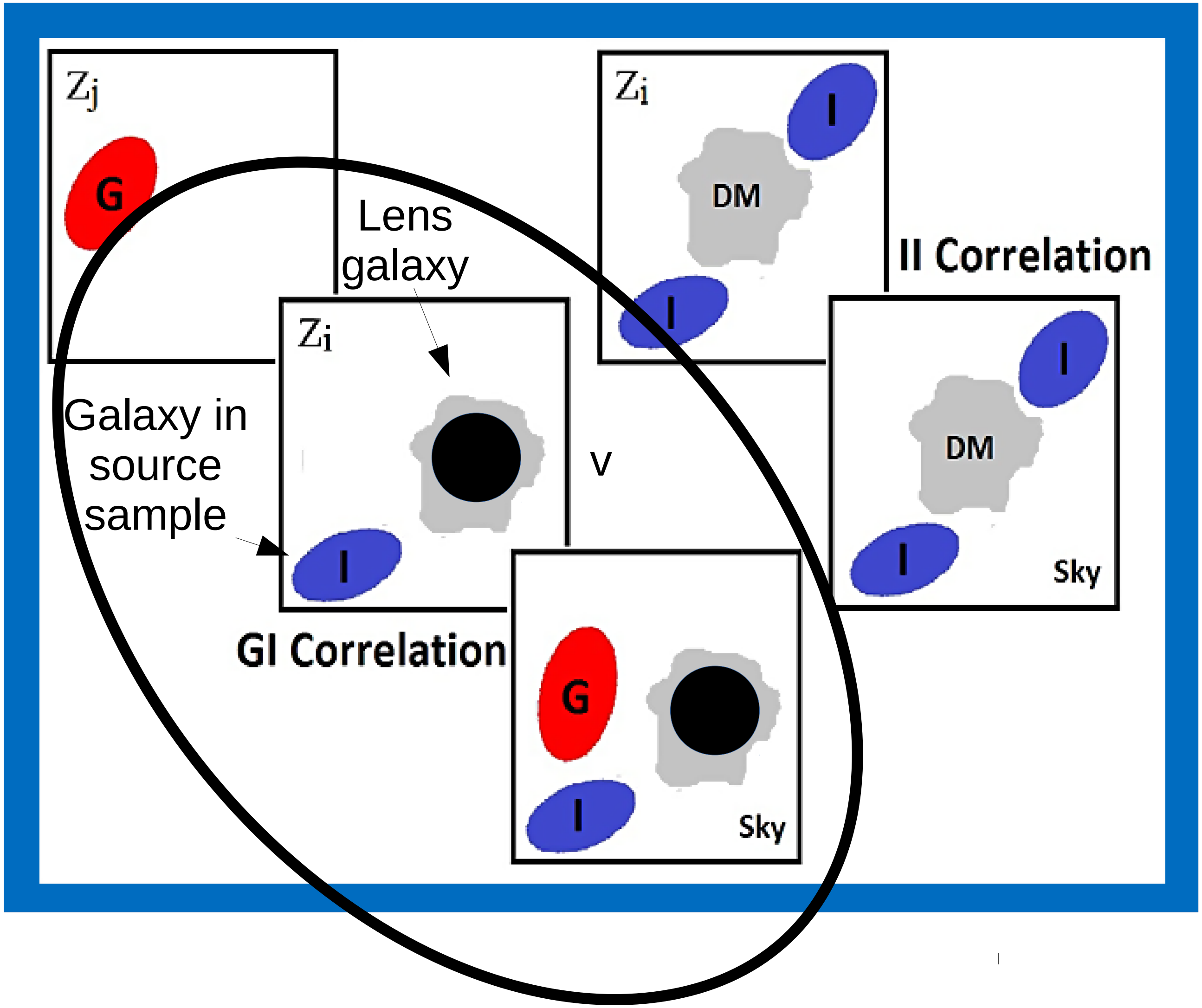


Image: Modifed from Troxel & Ishak 2012, 1203.2138

Outline

- Background and motivation
- **A new method for measuring IA**
- Forecasting method performance
- Conclusions

Intrinsic alignments and shear-estimation methods

Measured Intrinsic Alignment Amplitude ⟷ **Radial sensitivity of shear-estimation method**

Tenneti et al. 2014, 2015; Velliscig et al. 2015 (Sims)
Schneider et al. 2013; Singh et al. 2016 (Observations)

Singh et al. 2016:

Change the radial sensitivity of shear-estimation method
→ Multiply the measured IA amplitude by a **constant**

Measuring Intrinsic Alignments with Multiple Shear Estimates

Use this simple relationship to learn about the scale-dependence of the IA contamination to galaxy-galaxy lensing

Schematically:

Measured shear 1 = Lensing + IA
Measured shear 2 = Lensing + (constant a) IA

Measuring Intrinsic Alignments with Multiple Shear Estimates

Use this simple relationship to learn about the scale-dependence of the IA contamination to galaxy-galaxy lensing

Schematically:

Measured shear 1 = Lensing + IA
Measured shear 2 = Lensing + (constant a) IA

↓

(constant a) IA = Measured shear 1 – Measured shear 2

Measuring Intrinsic Alignments with Multiple Shear Estimates

Explicitly:

Tangential shear, method 1

Tangential shear, method 2

$$(1-a)\bar{\gamma}_{\mathrm{IA}}(r_p) = \frac{\tilde{\gamma}_t(r_p) - \tilde{\gamma}'_t(r_p)}{B(r_p) - 1 + F}$$

IA shear contribution per contributing galaxy

Boost factor

IA randoms ÷ All randoms

Measuring Intrinsic Alignments with Multiple Shear Estimates

$$(1-a)\bar{\gamma}_{\rm IA}(r_p) = \frac{\tilde{\gamma}_t(r_p) - \tilde{\gamma}'_t(r_p)}{B(r_p) - 1 + F}$$

Two potential advantages to this method:

1. Less sensitive to systematic errors related to inadequately representative spectroscopic subsamples of source galaxies?

2. Correlated noise reduces statistical error?

Outline

- Background and motivation
- A new method for measuring IA
- **Forecasting method performance**
- Conclusions

Forecasting method performance

Two observational scenarios of interest:

SDSS – *allows for comparison with measurements*

SDSS LRG lens galaxies
SDSS shape-sample source galaxies

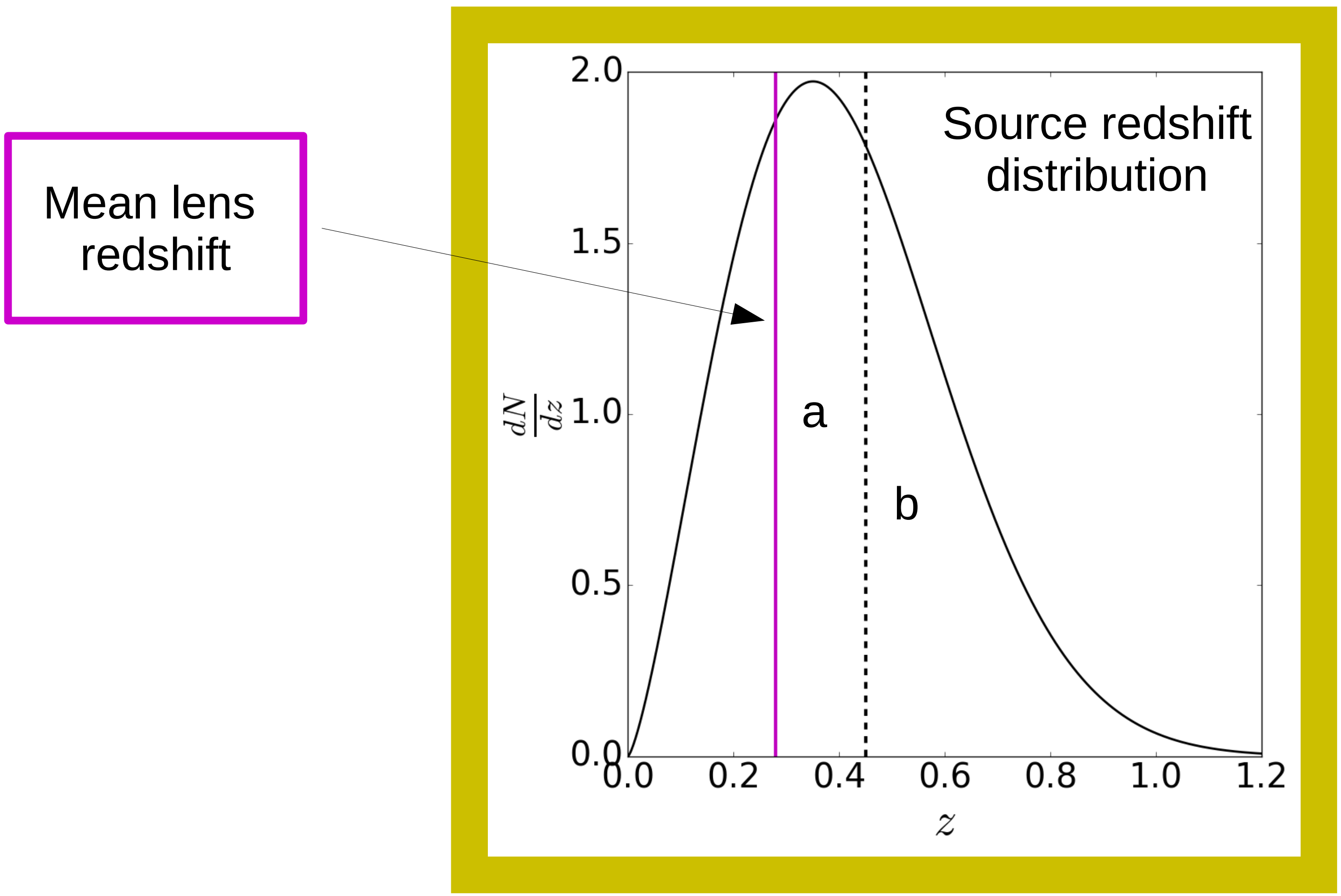
LSST+DESI – *next-generation surveys*

DESI LRG lens galaxies
LSST source galaxies

Forecasting method performance

Does our method improve upon standard existing methods?

Compare with: using the difference in lensing from different source photo-z bins, following *Blazek et al. 2012*



Comparing with an existing method

Using the difference in lensing from different source photo-z bins:
(*Blazek et al. 2012)*

$$\bar{\gamma}^{\rm IA}(r_p) = \frac{c_z^a \widetilde{\Delta\Sigma}^a(r_p) - c_z^b \widetilde{\Delta\Sigma}^b(r_p)}{(B^a(r_p) - 1)c_z^a \langle\tilde{\Sigma}_c\rangle_{\rm ex}^a(r_p) - (B^b(r_p) - 1)c_z^b \langle\tilde{\Sigma}_c\rangle_{\rm ex}^b(r_p)}$$

$\widetilde{\Delta\Sigma}$ → Observed lensing signal

B → Boost

$\langle\tilde{\Sigma}_c\rangle_{\rm ex}$ → Average critical surface density for excess galaxies

c_z → Parameterizes photometric redshift bias

Comparing with an existing method

Using the difference in lensing from different source photo-z bins:
(*Blazek et al. 2012)*

$$\bar{\gamma}^{\mathrm{IA}}(r_p) = \frac{c_z^a \widetilde{\Delta\Sigma}^a(r_p) - c_z^b \widetilde{\Delta\Sigma}^b(r_p)}{(B^a(r_p) - 1) c_z^a \langle \tilde{\Sigma}_c \rangle_{\mathrm{ex}}^a (r_p) - (B^b(r_p) - 1) c_z^b \langle \tilde{\Sigma}_c \rangle_{\mathrm{ex}}^b (r_p)}$$

Blazek et al. 2012 method: assumes **only excess** galaxy pairs are subject to IA.

Our method: assumes **all physically-associated** galaxy pairs are subject to IA.

Comparing with an existing method

Using the difference in lensing from different source photo-z bins, **assuming all physically-associated pairs are subject to IA** (following on *Blazek et al. 2012)*

$$\bar{\gamma}^{\rm IA}(r_p) = \frac{c_z^a \widetilde{\Delta\Sigma}^a(r_p) - c_z^b \widetilde{\Delta\Sigma}^b(r_p)}{(B^a(r_p) - 1 + F^a) c_z^a \langle\tilde{\Sigma}_c\rangle_{\rm IA}^a(r_p) - (B^b(r_p) - 1 + F^b) c_z^b \langle\tilde{\Sigma}_c\rangle_{\rm IA}^b(r_p)}$$

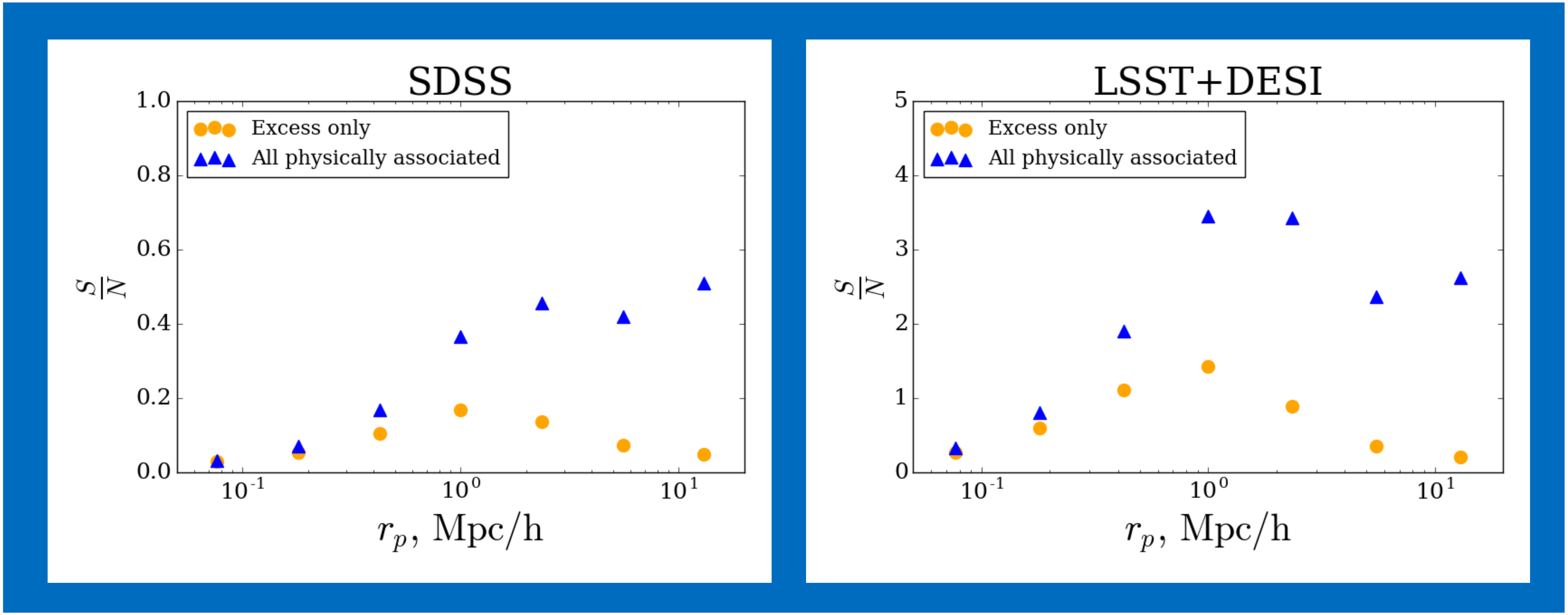
F → fraction of non-excess galaxy pairs which are physically-associated

$\langle\tilde{\Sigma}_c\rangle_{\rm IA}$ → Average critical surface density for all physically-associated pairs

Comparing with an existing method

Using the difference in lensing from different source photo-z bins, **assuming all physically-associated pairs are subject to IA** (following on *Blazek et al. 2012)*

PRELIMINARY



Comparing with an existing method

Using the difference in lensing from different source photo-z bins, **assuming all physically-associated pairs are subject to IA** (following on *Blazek et al. 2012)*

What's going on here?

$$\bar{\gamma}^{\rm IA}(r_p) = \frac{c_z^a \widetilde{\Delta\Sigma}^a(r_p) - c_z^b \widetilde{\Delta\Sigma}^b(r_p)}{(B^a(r_p) - 1 + F^a) c_z^a \langle\tilde{\Sigma}_c\rangle_{\rm IA}^a(r_p) - (B^b(r_p) - 1 + F^b) c_z^b \langle\tilde{\Sigma}_c\rangle_{\rm IA}^b(r_p)}$$

Comparing with an existing method

Using the difference in lensing from different source photo-z bins,
assuming all physically-associated pairs are subject to IA
(following on *Blazek et al. 2012)*

What's going on here?

$$\bar{\gamma}^{\mathrm{IA}}(r_p) = \frac{c_z^a \widetilde{\Delta\Sigma}^a(r_p) - c_z^b \widetilde{\Delta\Sigma}^b(r_p)}{(B^a(r_p) - 1 + F^a) c_z^a \langle \tilde{\Sigma}_c \rangle_{\mathrm{IA}}^a (r_p) - (B^b(r_p) - 1 + F^b) c_z^b \langle \tilde{\Sigma}_c \rangle_{\mathrm{IA}}^b (r_p)}$$

These terms prevent the fractional errors
on the boost from blowing up on large scales.

Forecasting: Systematic error comparison

Question: Is our method more robust to systematic uncertainties due to inadequately representative spectroscopic subsamples?

$$(1-a)\bar{\gamma}_{\rm IA}(r_p) = \frac{\tilde{\gamma}_t(r_p) - \tilde{\gamma}'_t(r_p)}{B(r_p) - 1 + F}$$

$$\bar{\gamma}^{\rm IA}(r_p) = \frac{c_z^a \widetilde{\Delta\Sigma}^a(r_p) - c_z^b \widetilde{\Delta\Sigma}^b(r_p)}{(B^a(r_p) - 1 + F^a)c_z^a \langle\tilde{\Sigma}_c\rangle^a_{\rm IA}(r_p) - (B^b(r_p) - 1 + F^b)c_z^b \langle\tilde{\Sigma}_c\rangle^b_{\rm IA}(r_p)}$$

Forecasting: Systematic error comparison

Question: Is our method more robust to systematic uncertainties due to inadequately representative spectroscopic subsamples?

$$(1-a)\bar{\gamma}_{\rm IA}(r_p) = \frac{\tilde{\gamma}_t(r_p) - \tilde{\gamma}'_t(r_p)}{B(r_p) - 1 + F}$$

$$\bar{\gamma}^{\rm IA}(r_p) = \frac{c_z^a \widetilde{\Delta\Sigma}^a(r_p) - c_z^b \widetilde{\Delta\Sigma}^b(r_p)}{(B^a(r_p) - 1 + F^a)c_z^a \langle\tilde{\Sigma}_c\rangle^a_{\rm IA}(r_p) - (B^b(r_p) - 1 + F^b)c_z^b \langle\tilde{\Sigma}_c\rangle^b_{\rm IA}(r_p)}$$

Galaxy-galaxy lensing observable

→ If systematic error on c_z^b is too high to measure lensing, we don't care about IA contamination.

Forecasting: Systematic error comparison

Question: Is our method more robust to systematic uncertainties due to inadequately representative spectroscopic subsamples?

Answer:

Yes – but in both methods, photo-z related errors are necessarily sub-dominant to statistical uncertainty when we can usefully measure lensing.

For galaxy-galaxy lensing with LSST + DESI:

$$\left(\frac{\sigma_{\rm sys}}{\sigma_{\rm stat}}\right)^{\rm max}_{\rm B2012} = 9\% \qquad \left(\frac{\sigma_{\rm sys}}{\sigma_{\rm stat}}\right)^{\rm max}_{\rm L2018} = 2\%$$

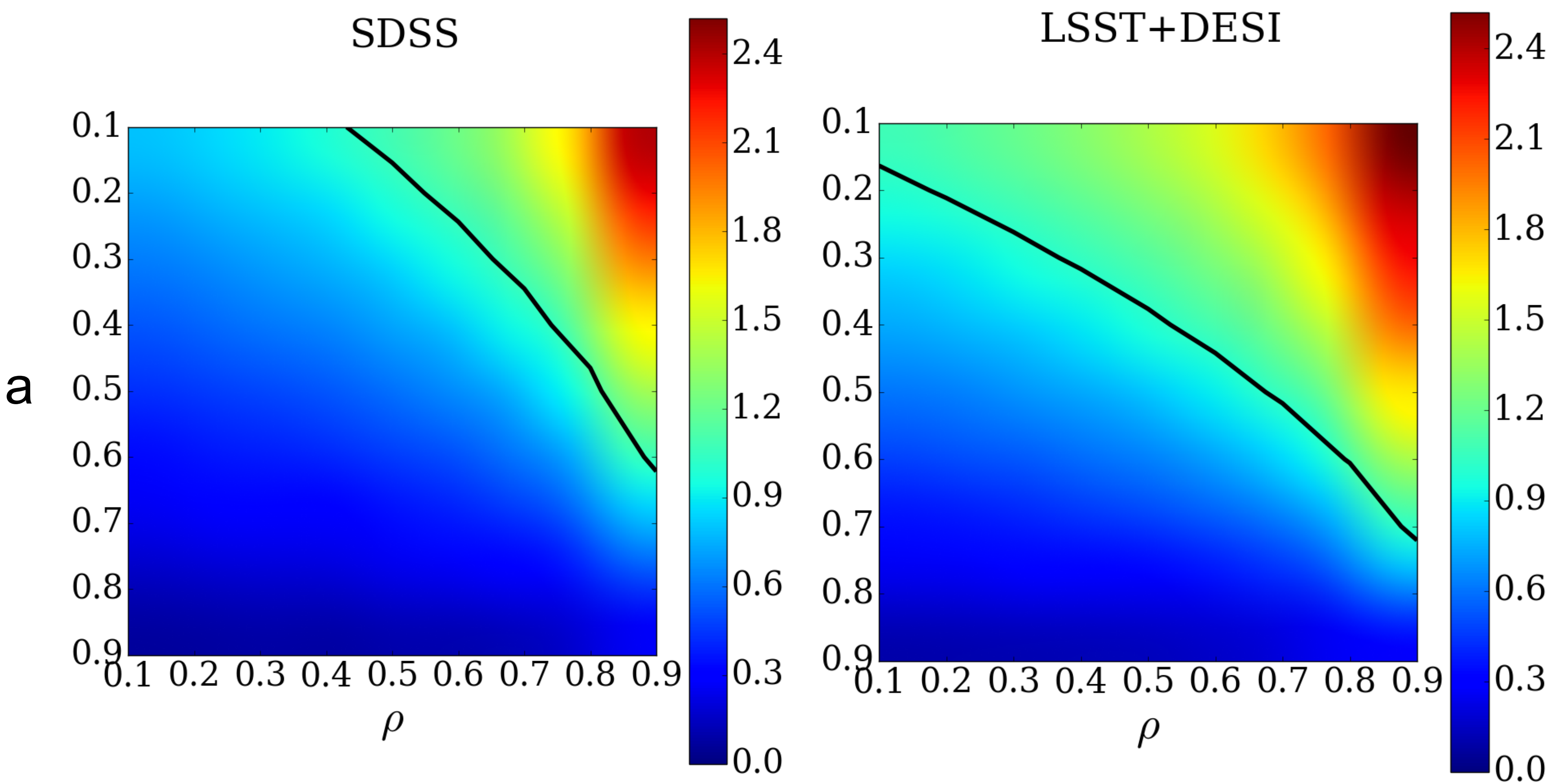
PRELIMINARY

Forecasting: Statistical error comparison

** + boost-related systematic error*

PRELIMINARY

$$\left(\frac{S}{N}\right)_{\mathrm{New}} \div \left(\frac{S}{N}\right)_{\mathrm{Existing}}$$

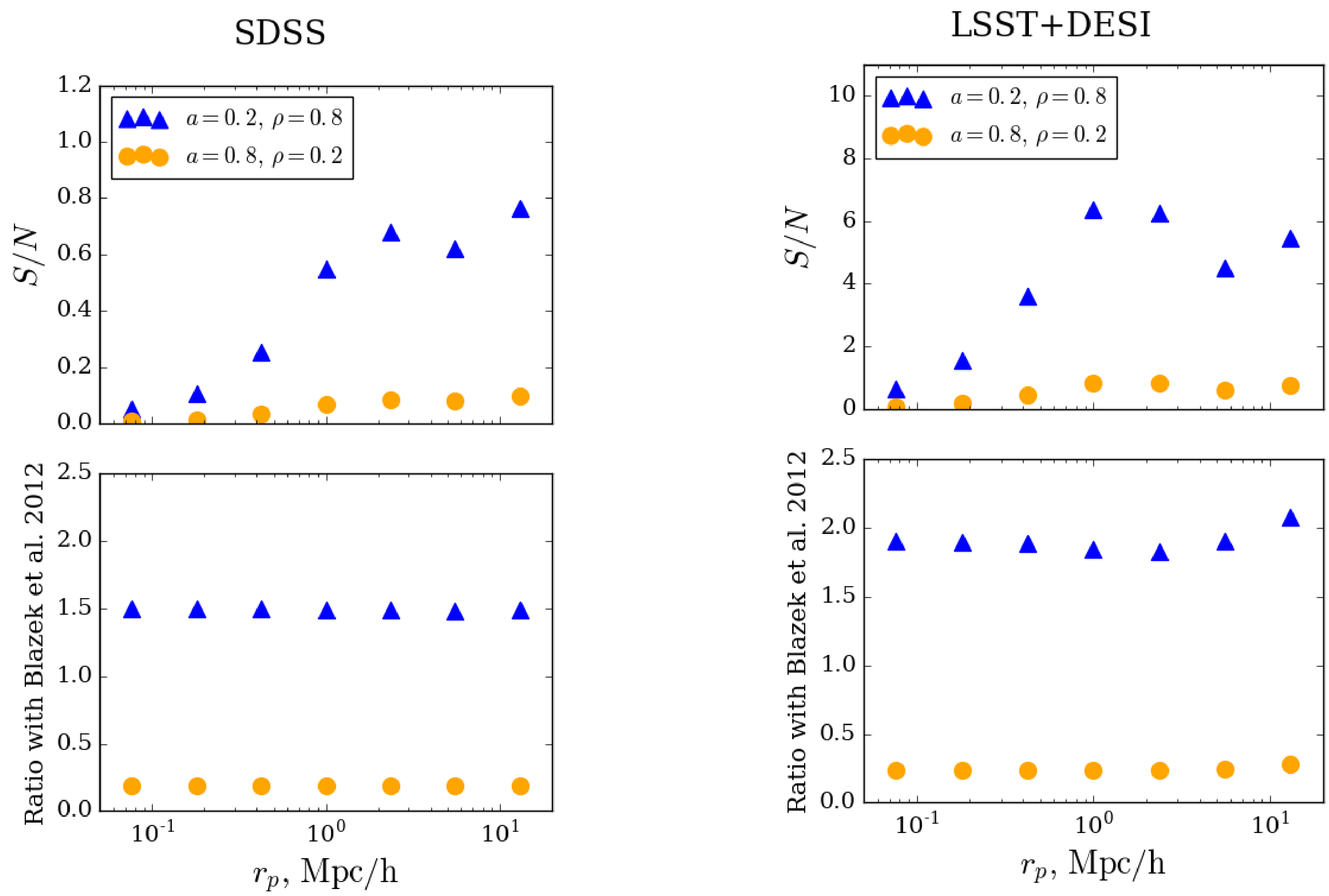


ρ = correlation coefficient

Forecasting: Statistical error comparison

** + boost-related systematic error*

PRELIMINARY



Outline

- Background and motivation
- A new method for measuring IA
- Forecasting method performance
- **Conclusions**

Summary and Conclusion

We have developed a new method for measuring the scale-dependence of IA contamination to G-G lensing.

Our method has the potential to do better than typical existing methods, especially for next-generation surveys e.g. LSST.

It is probably most useful in range of scales which connect the 2-halo and 1-halo regime.

Assuming that all physically-associated galaxy pairs may be subject to IA improves the method of *Blazek et al. 2012*.

Danielle Leonard
McWilliams Center for Cosmology,
Carnegie Mellon University
daniell1@andrew.cmu.edu