Title: Joint modeling of astrophysical systematics for cosmological surveys

Speakers: Niko Sarcevic

Series: Cosmology & Gravitation

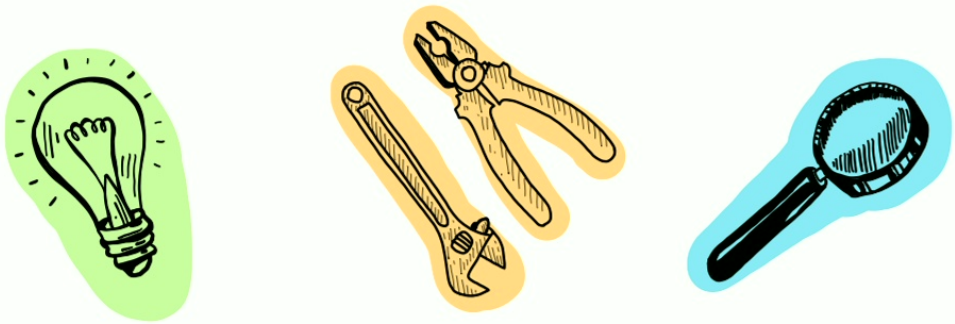
Date: May 14, 2024 - 11:00 AM

URL: https://pirsa.org/24050075

Abstract: In this talk, I will present a novel framework for modeling the weak lensing source galaxy redshift distribution and galaxy intrinsic alignment via a shared luminosity function. In the context of LSST Year 1 and Year 10 cosmic shear analysis, I demonstrate the significant impact of the luminosity function on source galaxy redshift distributions and intrinsic alignment contamination. I establish the influence of Schechter luminosity function parameters on the redshift distribution of a magnitude-limited sample and show the effects of marginalizing over these parameters in intrinsic alignment modeling. I forecast how this joint modeling approach affects cosmological parameter constraints, finding that it yields constraints comparable to standard analyses while mitigating potential biases from incorrectly fixed luminosity function parameters. I highlight the specific impact of the luminosity function shape on the cosmic shear data vector and discuss the method's potential for modeling generic selection functions and extending to a 3x2pt analysis with galaxy bias incorporation. While focused on LSST cosmic shear, this framework is broadly applicable to weak lensing surveys.

Zoom link

JOINT MODELLING APPROACH TO SYSTEMATICS FOR COSMOLOGICAL SURVEYS



NIKO SARCEVIC

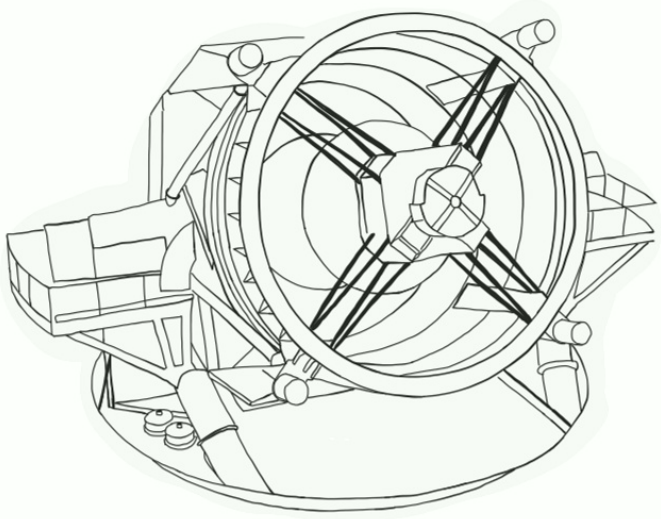
NEWCASTLE UNIVERSITY → DUKE UNIVERSITY

LSST DESC

PI, 14 MAY 2024

FRAMEWORK

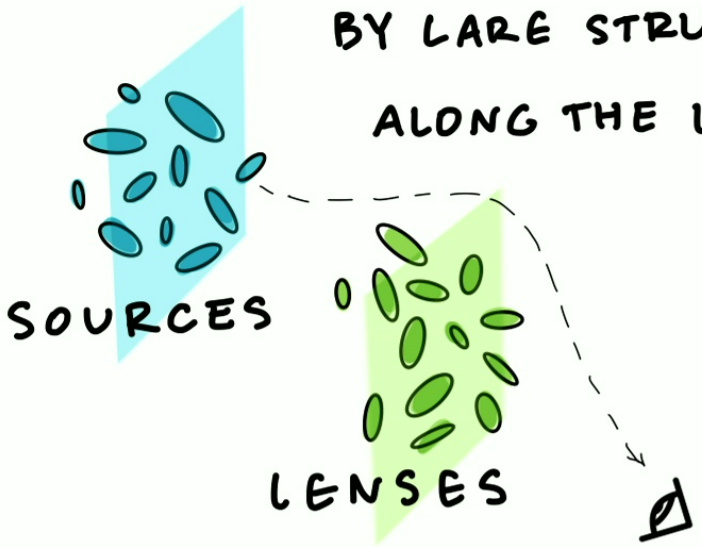
- LATE TIMES (GALAXIES)
- PHOTOMETRIC SURVEY (STAGE IV)
- HIGH PRECISION
- SYSTEMATICS
  ↓
  - INSTRUMENT
  - CALIBRATION
  - ASTROPHYSICS
  - ANALYSIS



LSST / RUBIN OBSERVATORY

GRAVITATIONAL LENSING

LIGHT DEFLECTION
BY LARE STRUCTURES
ALONG THE LOS



A STATISTICAL MEASUREMENT
OF COSMOLOGICAL PARAMETERS

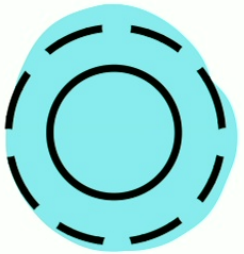
GRAVITATIONAL LENSING

BOILS DOWN TO COORDINATE TRANSFORMATION

TWO LIMITS:

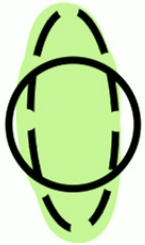
- **STRONG**: MAGNIFICATION

  κ 1 GALAXY



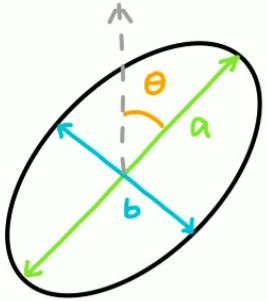
- **WEAK**: SHEAR

  γ SAMPLE



GRAVITATIONAL LENSING

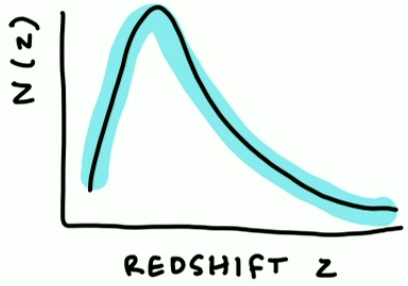
WHAT ? → GALAXY SHAPES



$$= f(a, b, \theta)$$

$$\varepsilon = \frac{a-b}{a+b} \exp(2i\theta)$$

WHERE ? → REDSHIFT DISTRIBUTION PZ



$$N(z) = \left(\frac{z}{z_0}\right)^m \exp\left(-\frac{z}{z_0}\right)^n$$

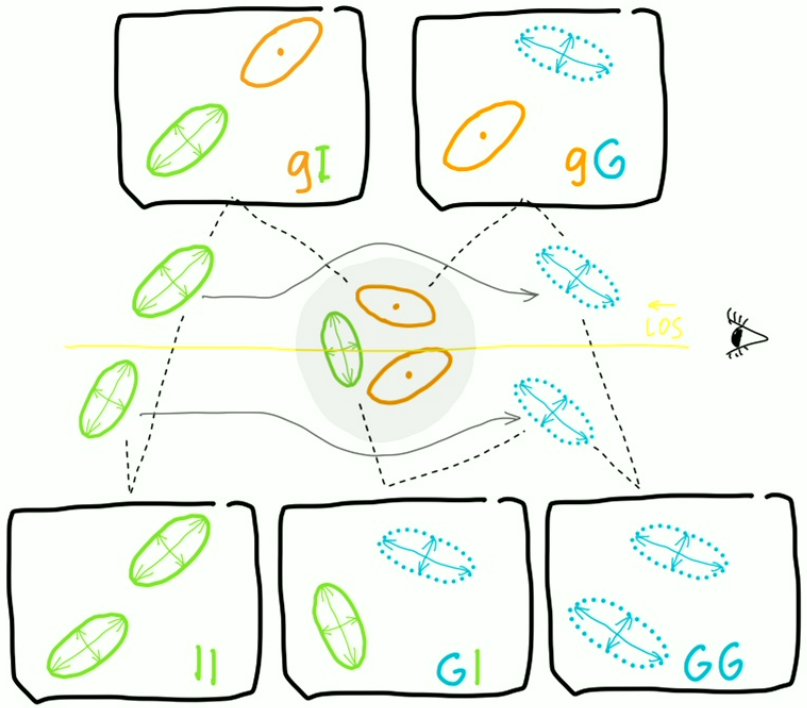
CORRELATIONS & ESTIMATORS

SHAPE - SHAPE

$$\langle \epsilon_i \epsilon_j \rangle = \langle G_i G_j \rangle + \langle I_i I_j \rangle + \langle G_i I_j \rangle + \langle I_i G_j \rangle$$

SHAPE - DENSITY

$$\langle \epsilon_i n_j \rangle = \langle G_i n_j \rangle + \langle I_i n_j \rangle$$

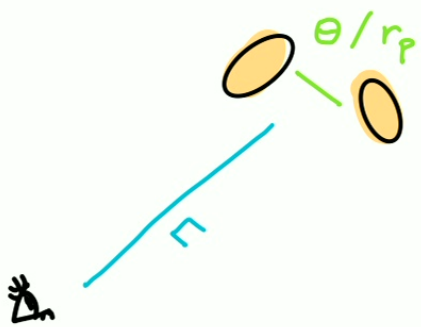


OBSERVABLE / STATS

HOW DO WE QUANTIFY THE CORRELATIONS?

TWO-POINT CORRELATION FUNCTION (2PCF)

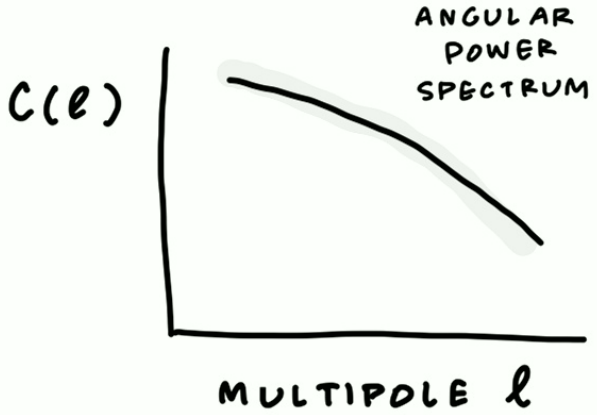
$$\xi_{+/-}(\Pi, r_p // \theta)$$



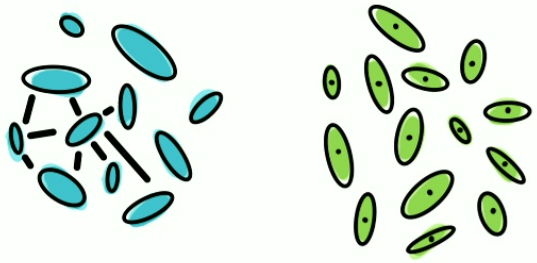
3D: $P(k)$ (FT of ξ)

2D: C_ℓ (PROJECTED)

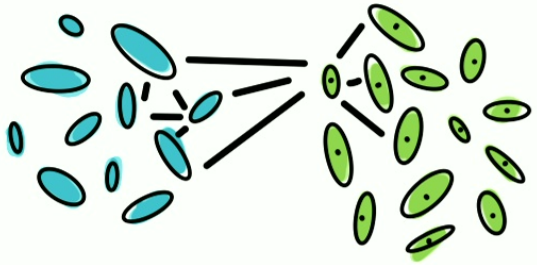
IN THIS WORK



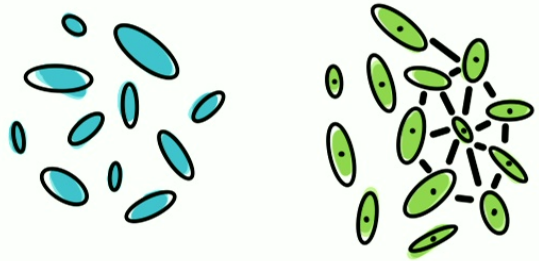
CORRELATIONS IN PRACTICE



SHAPE - SHAPE
COSMIC SHEAR



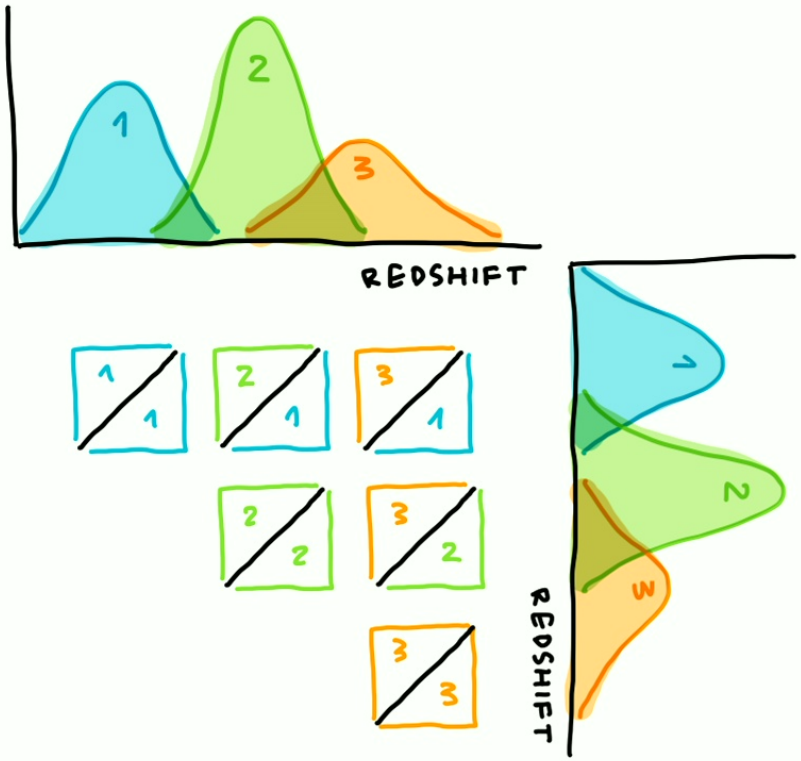
SHAPE - POSITION
GALAXY - GALAXY LENSING



POSITION - POSITION
GALAXY CLUSTERING

3x2 PT

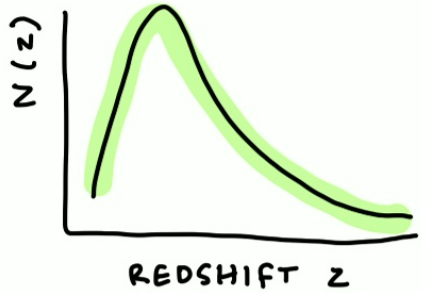
CORRELATIONS IN PRACTICE



TOMOGRAPHIC BINS

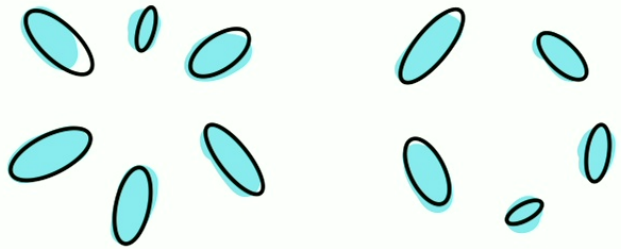
THE PROBLEM / SYSTEMATICS

REDSHIFT DISTRIBUTION PZ



A REDSHIFT ESTIMATE
PHOTOMETRY
CHEAP BUT TRICKY

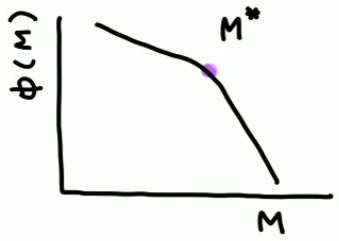
INTRINSIC ALIGNMENTS IA



DIFFRENT FROM SHEAR
GALAXY FORMATION EVOLUTION
BELOW % EFFECT

MITIGATION TECHNIQUES ?

PROJECT IDEA : JOINT MODELLING



NZ

$N(z) = \Delta V \, \Delta\phi$

LUMINOSITY FUNCTION

IA

$A \propto A_0 \left(L/L^*\right)^{\beta} \left(\frac{1+z}{1+z_0}\right)^{\eta}$

$\Phi(L)dL = \Phi^* \left(L/L^*\right)^{\alpha} \exp\left(-L/L^*\right)$

NUMBER DENSITY OF GALAXIES IN A LUMINOSITY AND REDSHIFT RANGE

THE PLAN

STEP 1 : MODEL N(z) w/ LF

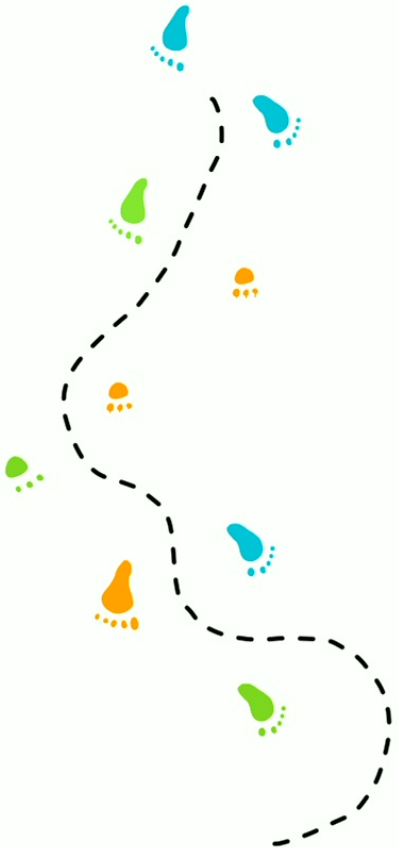
STEP 2 : MODEL IA w/ LF

STEP 3 : PRODUCE A FORECAST

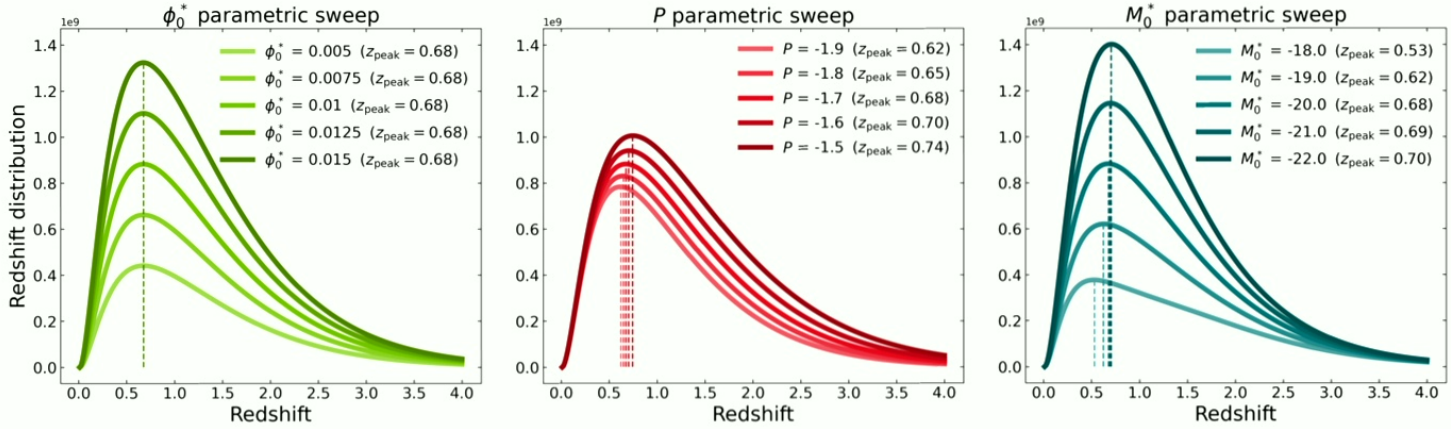
STEP 4 : COMPARE TO BENCHMARK

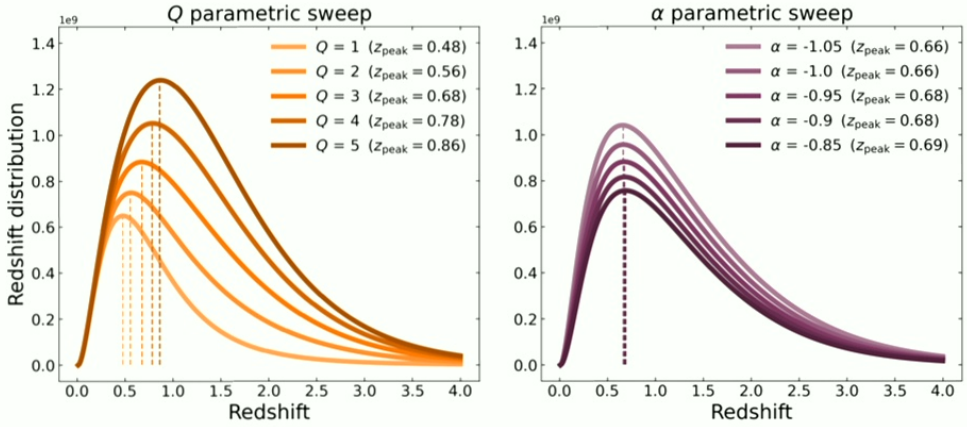
STEP 5 : DEGENERACIES

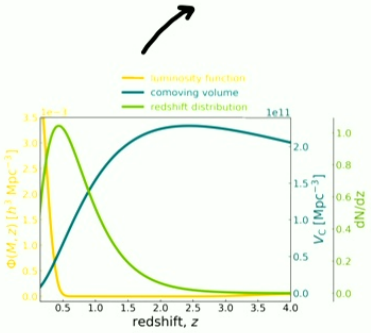
PROBE : COSMIC SHEAR



JOINT MODELLING : STEP 1





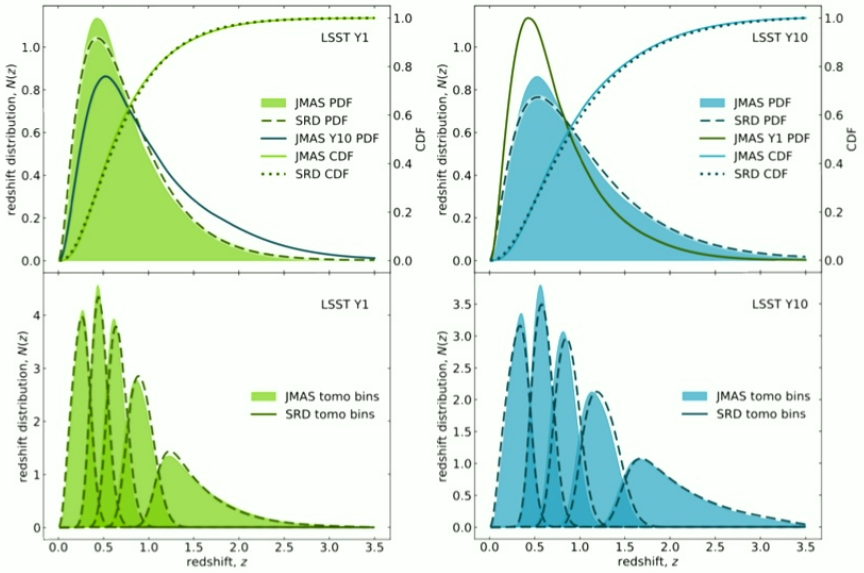


N(z) MODELLING

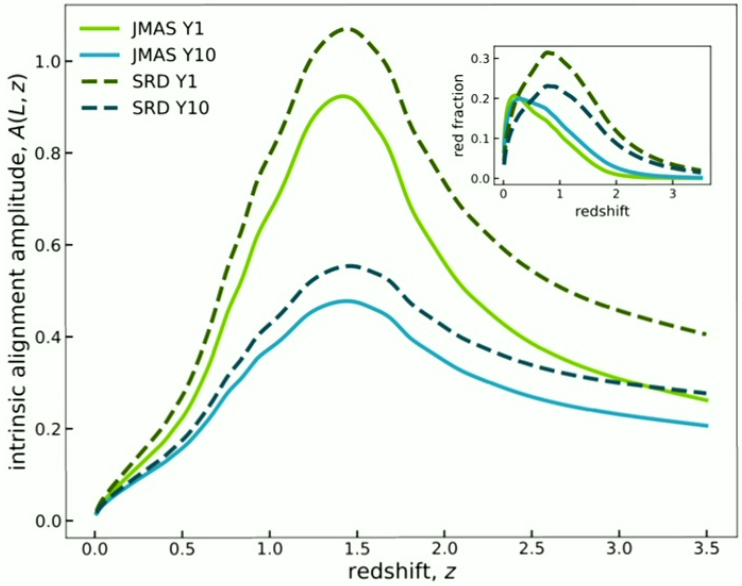
JOINT MODELLING : STEPS 1 & 2

SRD: LSST FORECAST

JMAS : THIS WORK



N(z)



IA

JOINT MODELLING : STEP 3

- CAN IT BE DONE?
- IF SO – WHAT IS THE IMPACT ON COSMOLOGICAL CONSTRAINTS
- PARAMETER ESTIMATION

$$p(\theta|x) \rightharpoonup p(x|\theta)$$

POSTERIOR PROBABILITY FORWARD MODEL

BAYESIAN APPROACH:

$$p(\theta|x) \propto p(x|\theta)\, p(\theta)$$

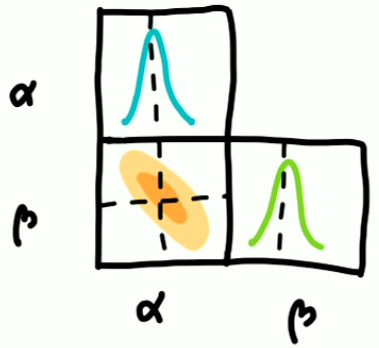
POSTERIOR $\propto$ LIKELIHOOD $\times$ PRIOR

A BAYESIAN APPROACH

- MONTE CARLO
- FISHER ANALYSIS / FORECAST

ERROR ON THE PARAMETER $\sigma_\alpha = \mathrm{sqrt}\left(H^{-1}_{\alpha\alpha}\right)$

HESSIAN MATRIX



$$F_{\alpha\beta} \equiv \langle H_{\alpha\beta} \rangle = \left\langle \frac{\partial^2 \ln \mathcal{L}}{\partial\theta_\alpha \partial\theta_\beta} \right\rangle$$

FISHER MATRIX

$$\sigma_\alpha = \mathrm{sqrt}\left(F_{\alpha\alpha}\right)$$

HOW ACCURATELY CAN WE ESTIMATE MODEL PARAMETERS FROM A GIVEN DATASET?

FISHER FORECAST

DATA VECTOR $C(\ell)$

↓

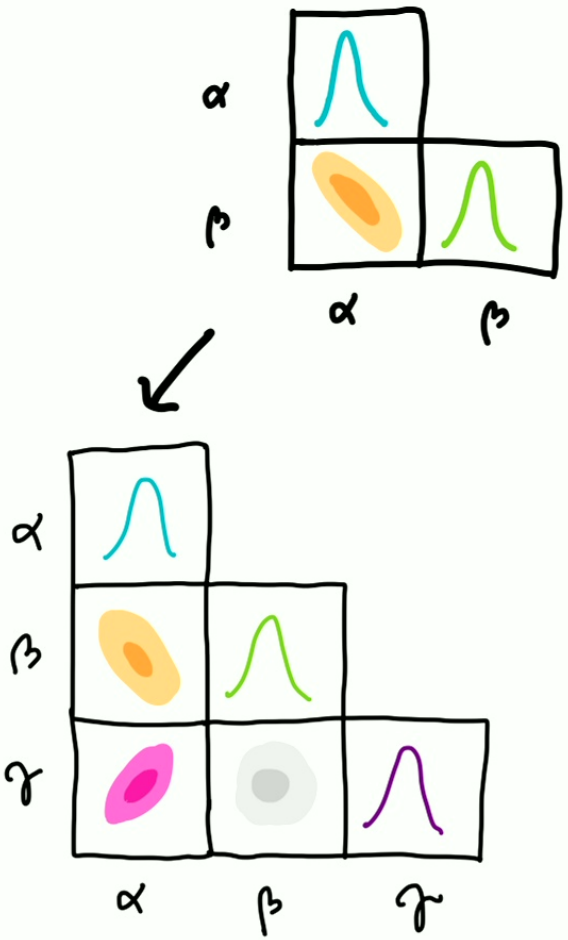
DERIVATIVES OVER PARAMETERS

↓

FISHER MATRIX

PARAMETER SPACE

- COSMO 7
- IA 9
- LF 5



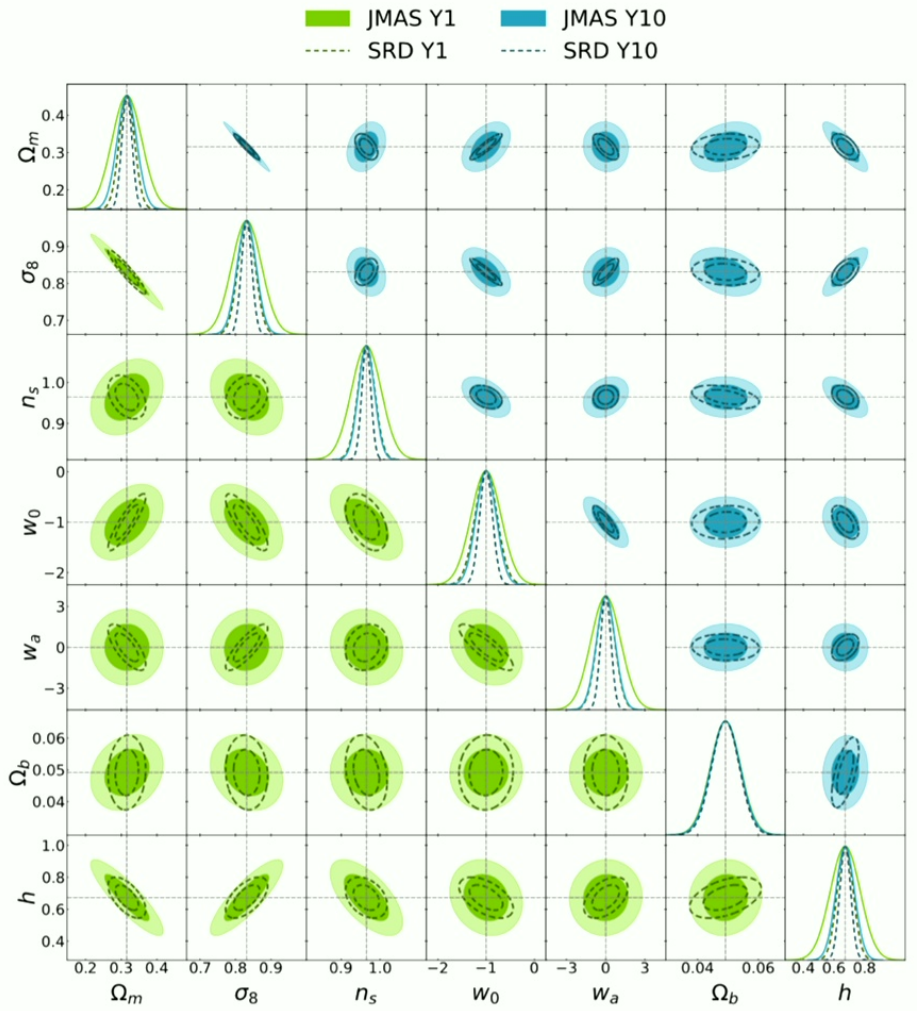
THE RESULT

- JMAS : THIS WORK
- SRD : PREVIOUS FORECAST

DOES IT WORK? YES :)

MAIN CONCLUSION :

- GOOD AGREEMENT
- NEGLIGIBLE LOSSES
- WIDER : EXPECTED



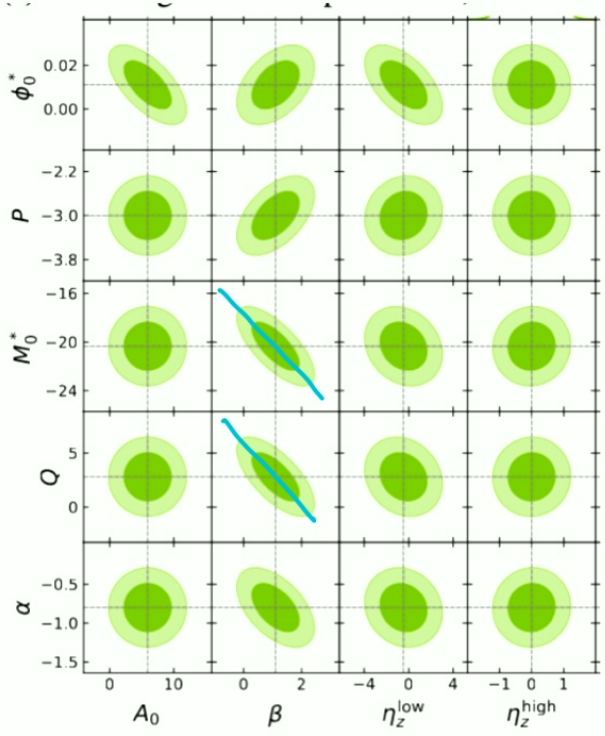
THE RESULT

CORRELATIONS

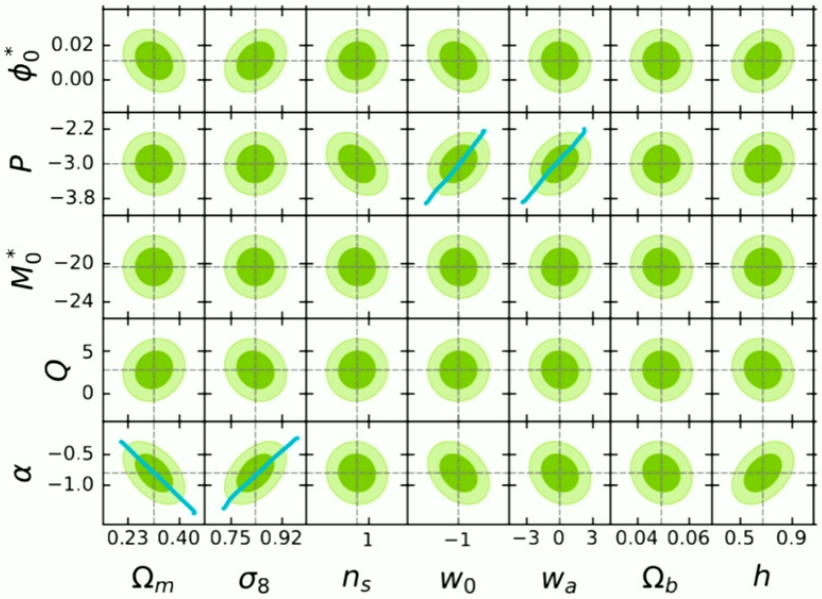
EXTRA INFO :

BETWEEN LF / COSMO
\ IA

PARAMS



LF & IA



LF & COSMO

CONCLUSION

- WL : A POWERFUL PROBE
- UPCOMING SURVEYS
- SYSTEMATICS HANDLING
- JOINT MODELLING TECHNIQUE
- NEXT

3x2PT
MCMC
PRIORS FROM SIMS
TEST ON DATA
SELECTION FUNCTION MODELLING

THANKS A BUNCH!