IRFU PHD STUDENT SEMINAR

A fast stochastic approach for cosmological constraints using weak-lensing peak counts

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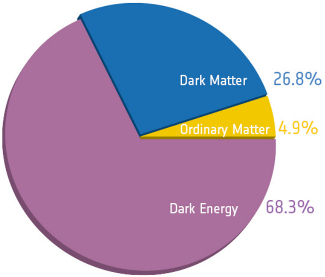
SAp, CEA Saclay

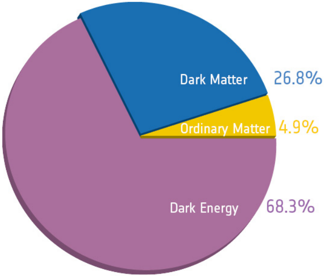
Irfu, CEA Saclay — July 2nd, 2015

Context



(Source: Planck)

Context



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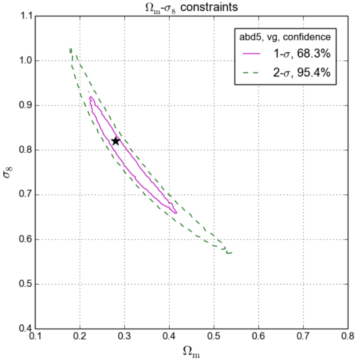

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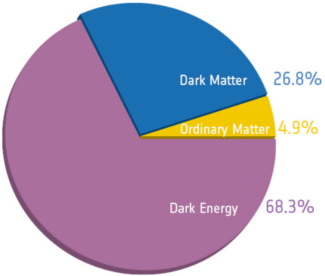

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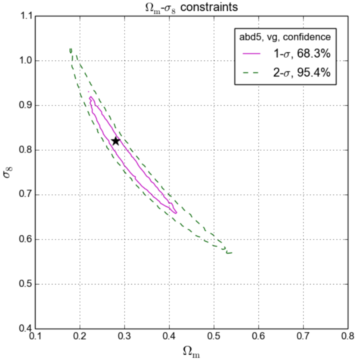


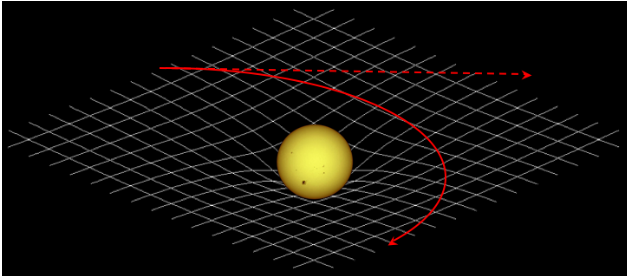
To constrain cosmological parameters

Outline

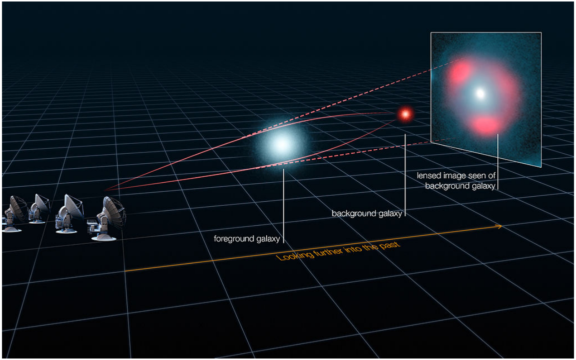
Outline

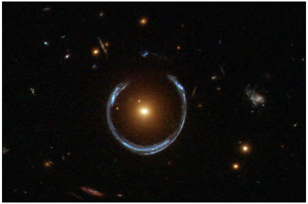
What is weak lensing?

Light deflection in general relativity



What is weak lensing?



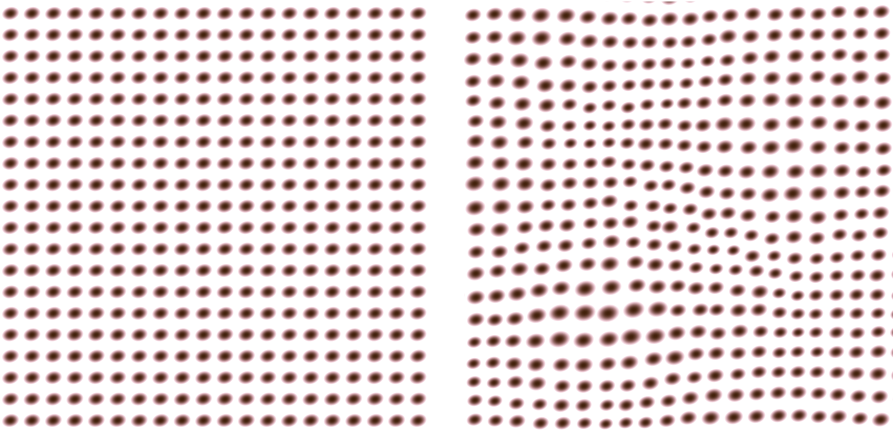


Strong lensing: Einstein ring

(Source: ALMA, ESA-Hubble, NASA)

What is weak lensing?

Weak lensing

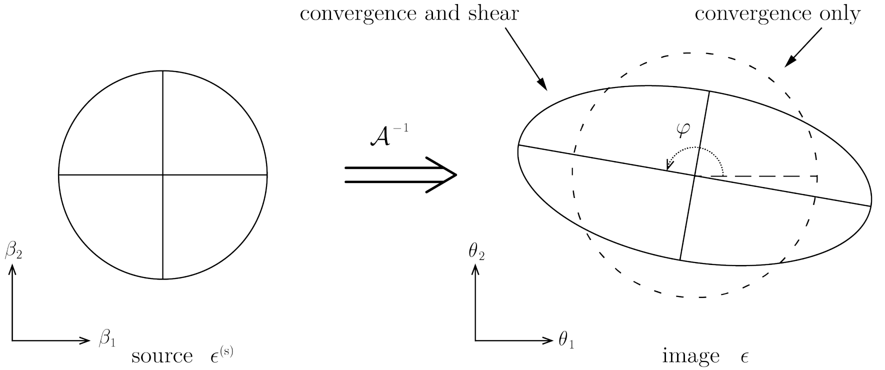


What is weak lensing?

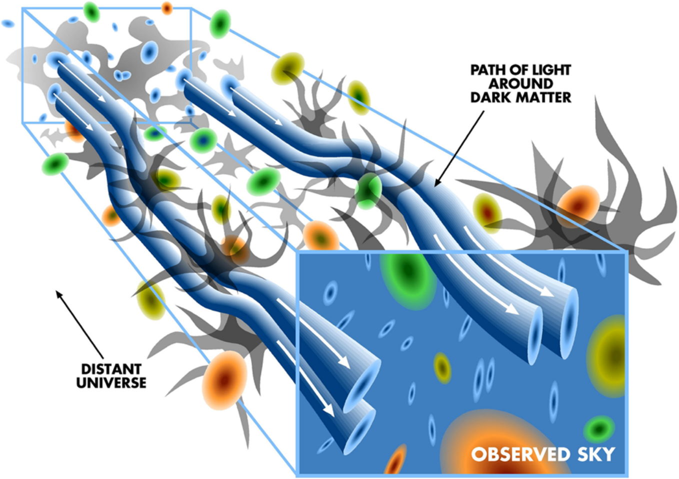
$$\mathcal{A}(\boldsymbol{\theta}) = \begin{pmatrix} 1-\kappa-\gamma_1 & -\gamma_2 \\ -\gamma_2 & 1-\kappa+\gamma_1 \end{pmatrix}$$

κ: convergence, “projected mass density”

$\gamma = \gamma_1 + \mathrm{i}\gamma_2$: cosmic shear, distortion



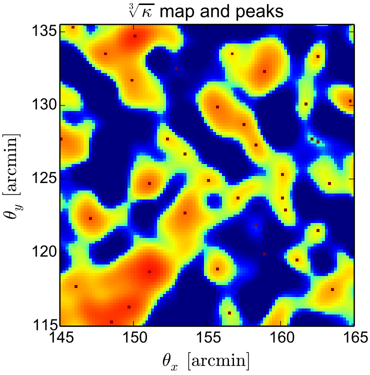
What is weak lensing?

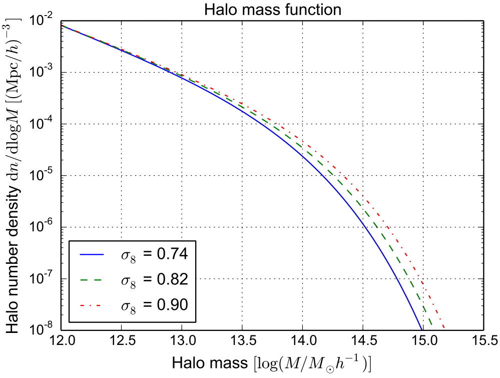


(Source: LSST)

Outline

Peak counts from weak lensing





- Local maxima of the projected mass
- Direct tracers of massive regions
- Probe mass function

Peak counts from weak lensing

Peak counts are part of higher-order statistics, complementary to Gaussian information

Peak-count modeling

- Analytical models
- N-body simulations
- Fast stochastic methods (this talk)

Difficulties

- Observational effects: photo-z, masks, and others
- Additional features: intrinsic alignment, baryonic effects

Challenges

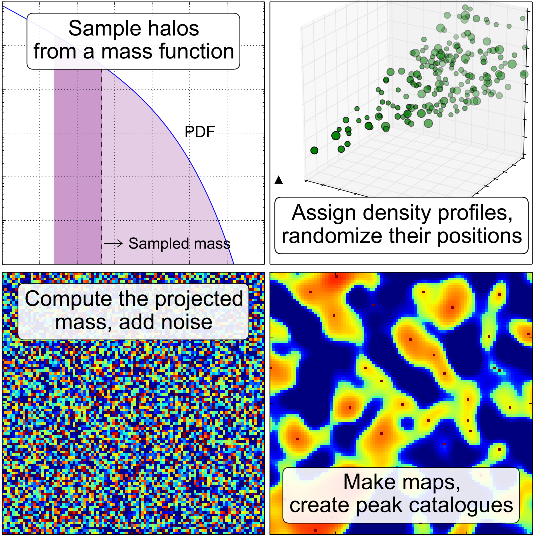
How to predict weak-lensing peak counts in realistic conditions?

How to extract cosmological information from peaks?

Outline

Our model

A fast stochastic forward model (See Lin & Kilbinger 2015a, A&A, 576, A24 for details)



Our model

Hypotheses

- Diffuse, unbound matter does not significantly contribute to peak counts
- Spatial correlation of halos has a minor influence

Public code

CAMELUS

Counts of Amplified Mass Elevations
from Lensing with Ultrafast Simulation

http://www.cosmostat.org/software/camelus/

Advantages

Fast

Flexible

Full PDF information

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Only few seconds for creating a 25-deg^2 field, without MPI or GPU programming

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Straightforward to include observational effects (e.g. photo-z errors, masks) and additional features (e.g. intrinsic alignment, baryonic effects)

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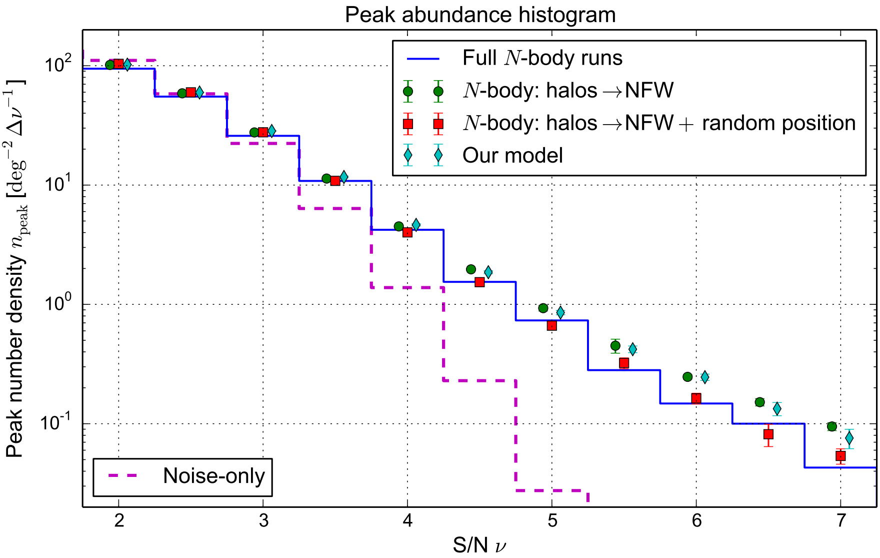
Full PDF information

Free from the Gaussian likelihood assumption, allow more flexible constraint methods (copula, varying covariances, p-value evaluation, approximate Bayesian computation, etc.)

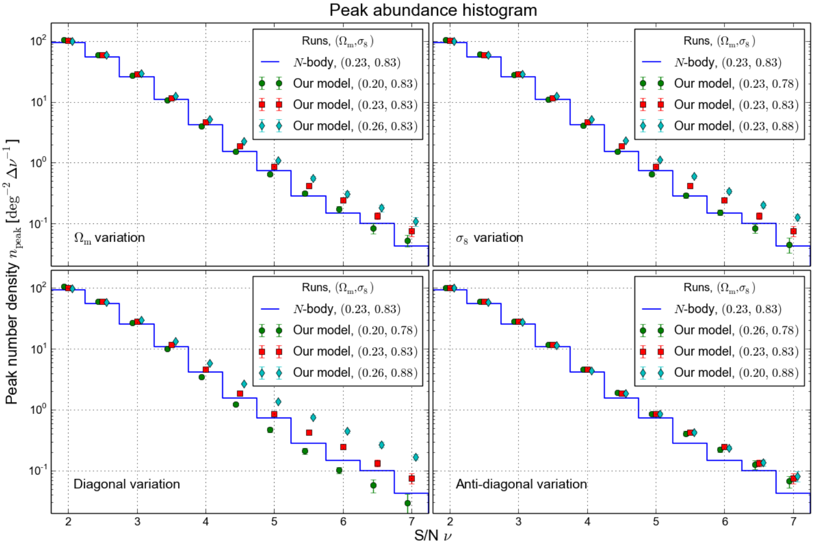
Outline

Validation



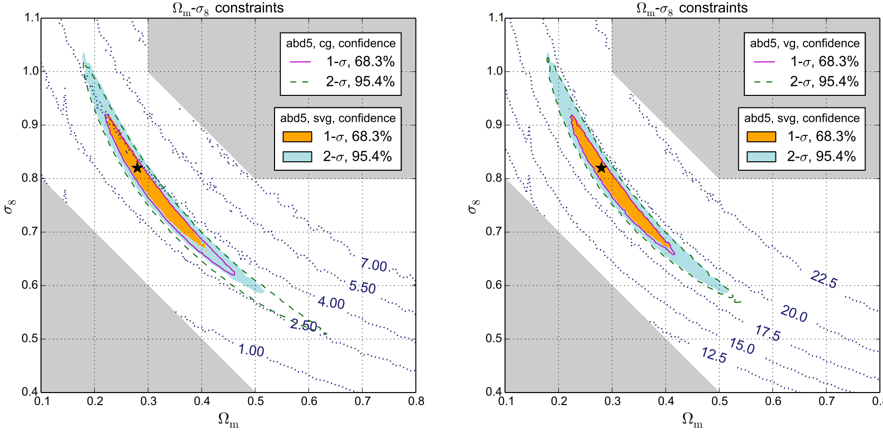
Lin & Kilbinger (2015a)

Dependance on parameters



Lin & Kilbinger (2015a)

Cosmology-dependent covariances



cg = constant covariance (lines, left panel)

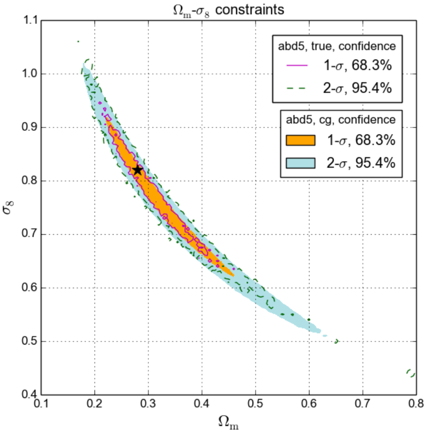
svg = semi-varying covariance (colored zones)

vg = varying covariance (lines, right panel)

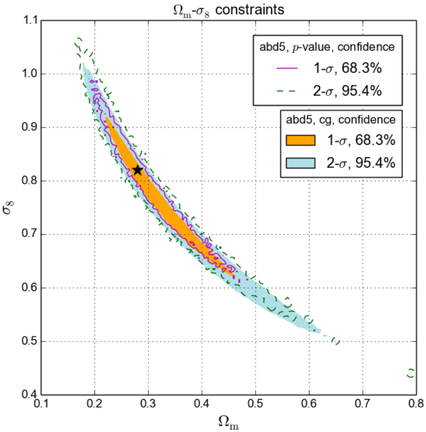
	cg	svg	vg
FoM	46	57	56

Lin & Kilbinger (2015b)

Non-analytical constraints



With the true likelihood



With p-value

Lin & Kilbinger (2015b)

Approximate Bayesian computation

Approximate Bayesian computation (ABC) is an efficient technique which provides constraints by bypassing likelihood estimation.

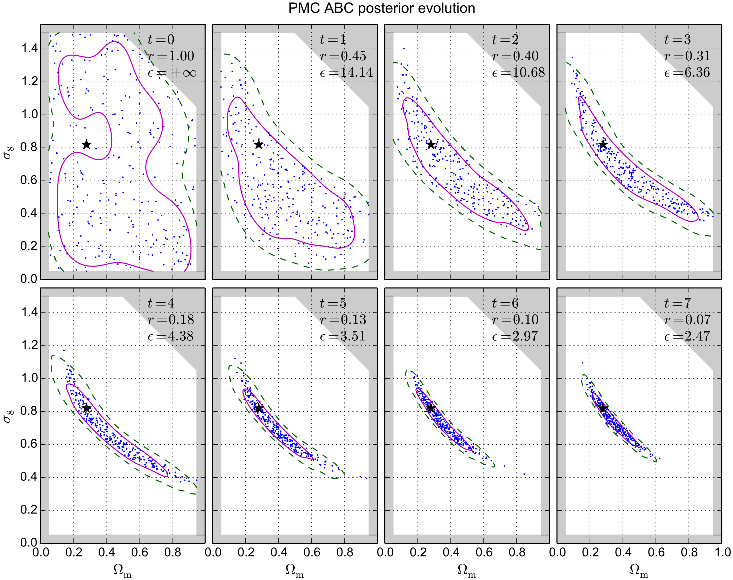
This is an accept-reject process which samples directly under an approximate posterior.

Requirements

- Stochastic model
- Suitable data vector
- Metric

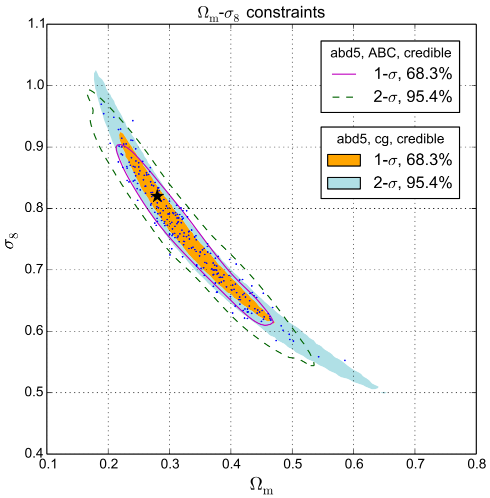
This is combined with the population Monte Carlo technique (PMC), a time series solution for accelerating the algorithm.

Approximate Bayesian computation



Lin & Kilbinger (2015b)

Approximate Bayesian computation



Very good agreement

Time comparison:

- Likelihood $\approx 8000 \times 1000$ simulations to run
- ABC $\approx 250 \times 1 \times 100$ simulations to run

Lin & Kilbinger (2015b)

Outline

Future works

- Peak extraction from nonlinear filters
- Intrinsic ellipticity alignment
- Baryonic effects
- Tomography studies
- Application to CFHTLenS data

Summary

- A fast stochastic model for WL peak counts
- Fast, flexible, full PDF information
- A robust and efficient constraining method: ABC

Thank you for your attention

http://www.cosmostat.org/software/camelus/

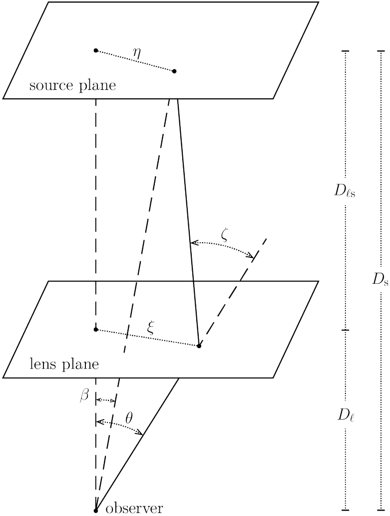
http://linc.tw/

Backup slides

Born approximation

$$\mathcal{A}_{ij}(\boldsymbol{\theta}) = \delta_{ij} - \frac{2}{\mathrm{c}^2}\int_0^w \mathrm{d}w' \, \frac{f_K(w-w')f_K(w')}{f_K(w)} \times \, \phi_{,ij}\left(f_K(w')\boldsymbol{\theta}, w'\right)$$

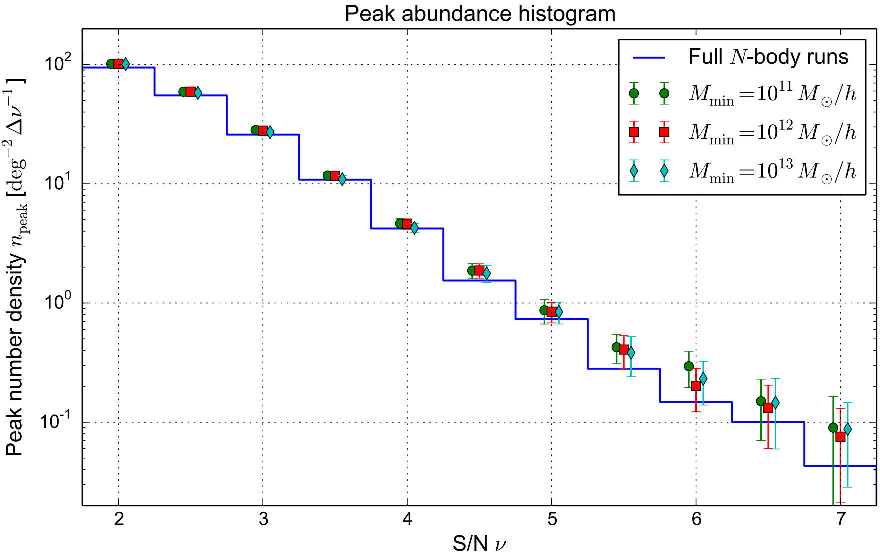
$$\kappa(\boldsymbol{\theta}, w) = \frac{3H_0^2\Omega_\mathrm{m}}{2\mathrm{c}^2}\int_0^w \mathrm{d}w' \, \frac{f_K(w-w')f_K(w')}{f_K(w)} \times \frac{\delta\left(f_K(w')\boldsymbol{\theta}, w'\right)}{a(w')}$$



Settings

- Fixed source redshift z_s = 1.0
- Galaxy number density n_g = 25 arcmin^{-2}
- Pixel size θ_pix = 0.2 arcmin
- Uncorrelated Gaussian shape noise, no IA
- Smoothing radius θ_G = 1 arcmin

Our model is not sensitive to $M_{\min}$



Approximate Bayesian computation

Steps

- Sample parameters π_i from the prior
- For each π_i, generate one x_i from the model
- Accept π_i if $|x_i - x^{\mathrm{obs}}| \leq \epsilon$, reject it otherwise
- Reconstruct the posterior from accepted π_i

Approximate Bayesian computation

ABC's accept-reject process is actually a sampling under P_ϵ (green curve):

$$P_\epsilon(\pi|x^{\text{obs}}) = A_\epsilon(\pi)P(\pi),$$

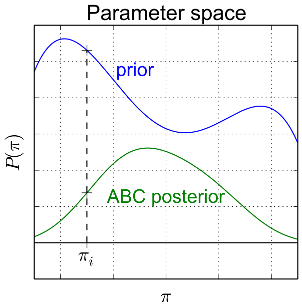
where $P(\pi)$ stands for the prior (blue curve) and

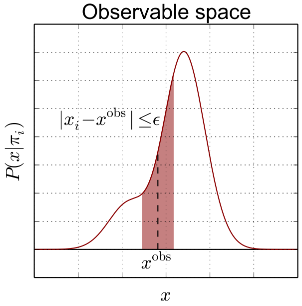
$$A_\epsilon(\pi) \equiv \int \mathrm{d}x\ P(x|\pi)\mathbb{1}_{|x-x^{\text{obs}}|\leq\epsilon}(x),$$

is the accept probability under π (red area). One can see that

$$\lim_{\epsilon\to 0} A_\epsilon(\pi_0)/\epsilon = P(x^{\text{obs}}|\pi_0) = \mathcal{L}(\pi_0),$$

so P_ϵ is proportional to the true posterior when $\epsilon \to 0$.





Publications

Refereed papers

- **Lin C.-A.**, Umetsu K., Kilbinger M., & Coupon J. (2015). In preparation.
- **Lin C.-A.** & Kilbinger M. (2015b). *A new model to predict weak-lensing peak counts II. Parameter constraint strategies*. Submitted to A&A.
- **Lin C.-A.** & Kilbinger M. (2015a). *A new model to predict weak-lensing peak counts I. Comparison with N-body simulations*. A&A, 576, A24.

Proceeding

- **Lin C.-A.** & Kilbinger M. *A New Model to Predict Weak Lensing Peak Counts*. Statistical Challenges in 21st Century Cosmology, Lisbon, May 2014.

Talks

- IAP Seminar Series, Paris, to be determined.
- IAS Seminar Series, Orsay, France, Jan 2015.
- ASIAA Seminar Series, Taipei, Jan 2015.
- International Workshop on Cosmology and Sparsity 2, Nice, Sep 2014.
- Euclid Consortium Meeting, Marseille, May 2014.
- DIM-ACAV Colloquium, Paris, Oct 2013.

Posters

- Theoretical and Observational Progress on Large-scale Structure of the Universe, Garching, Germany, Jul 2015.
- Statistical Challenges in 21st Century Cosmology, Lisbon, May 2014.

Experiences

Education

- 2012-2013: MSc in high energy physics, École Polytechnique, Palaiseau, France.
- 2009-2013: Diplôme d'ingénieur, École Polytechnique.
- 2007-2009: Classe préparatoire aux grandes écoles, Lycée Louis le Grand, Paris.
- Until 2007: Secondary education in Taichung, Taiwan.

Teaching

- Teaching assistant, Introduction to Quantum Mechanics, spring 2015, École Polytechnique.
- High school project supervisor, Matière noire, fall 2014.
- Teaching assistant, Nonlinear Optics MOOC, since fall 2014, École Polytechnique.
- Teaching assistant, Quantum Mechanics and Statistical Physics, spring 2013, École Polytechnique.
- High school level tutor, 2009-2010, Collège Saint-François, France.

Outreach & Miscellaneous

- PhD student representative for the Laboratory Council of SAp/AIM.
- Lin C.-A. (2015). *Popular Astrophysics from Interstellar*. Taiwan Natural Science, 125, 84.
- Popular science animator, 2013-2014, Palais de la découverte, Paris.
- Volunteer educator, 2009-2010, Collège Saint-François, France.