Imperfect models give imperfect constraints

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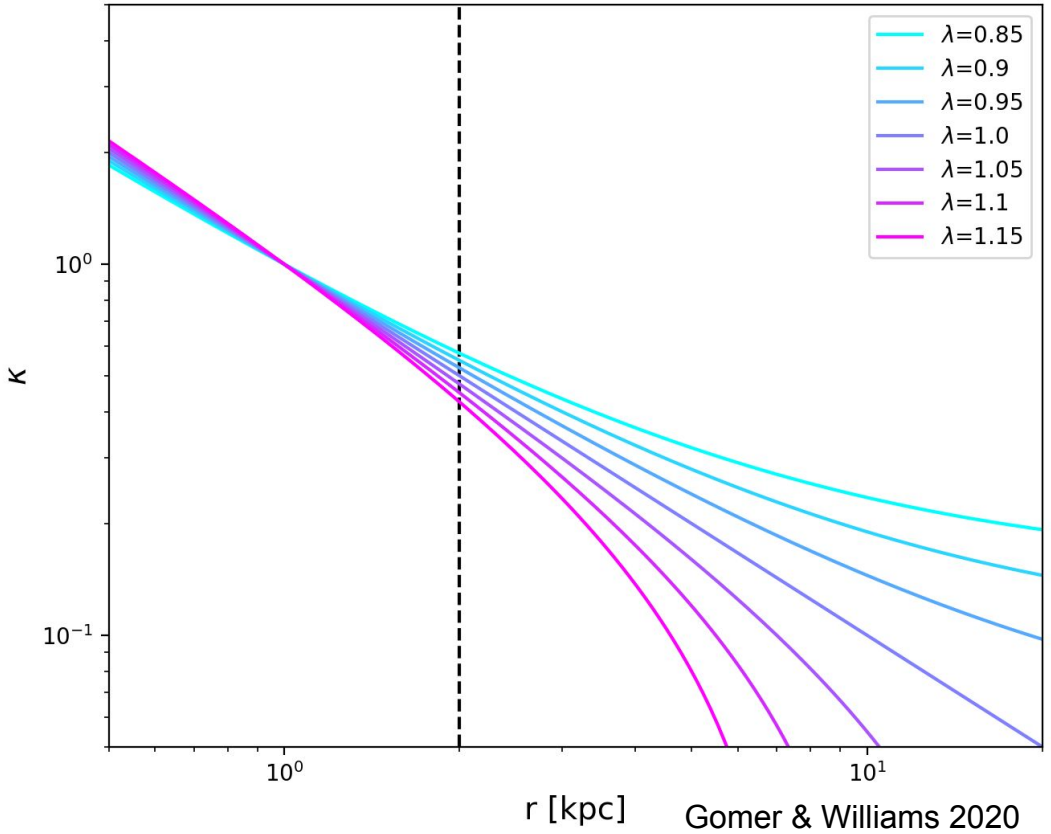
Recap: MSD

$$\kappa \rightarrow \lambda\kappa + (1-\lambda)$$

Mass sheet changes profile slope, but not observed image properties

Time delays ie. H_0 are affected:

$$H_0\Delta t \rightarrow \lambda\, H_0\Delta t$$



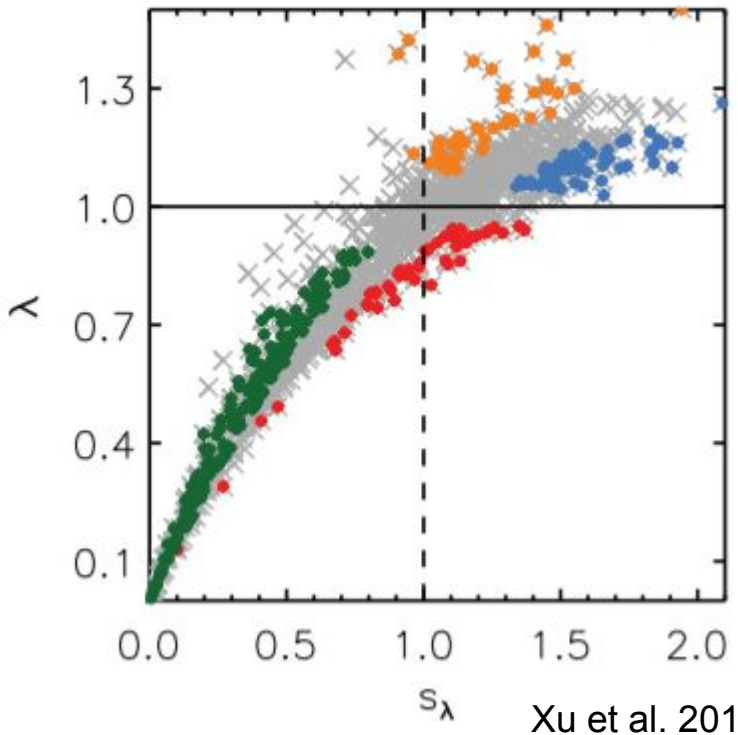
Gomer & Williams 2020

Analytical estimation of **λ** bias

From a profile, calculate the MST necessary to make it a power-law shape (the model used to fit the lens)

Corresponding **λ** should be a proxy for H_0 bias

$$H_0\Delta t \rightarrow \boldsymbol{\lambda}\, H_0\Delta t$$



Xu et al. 2016

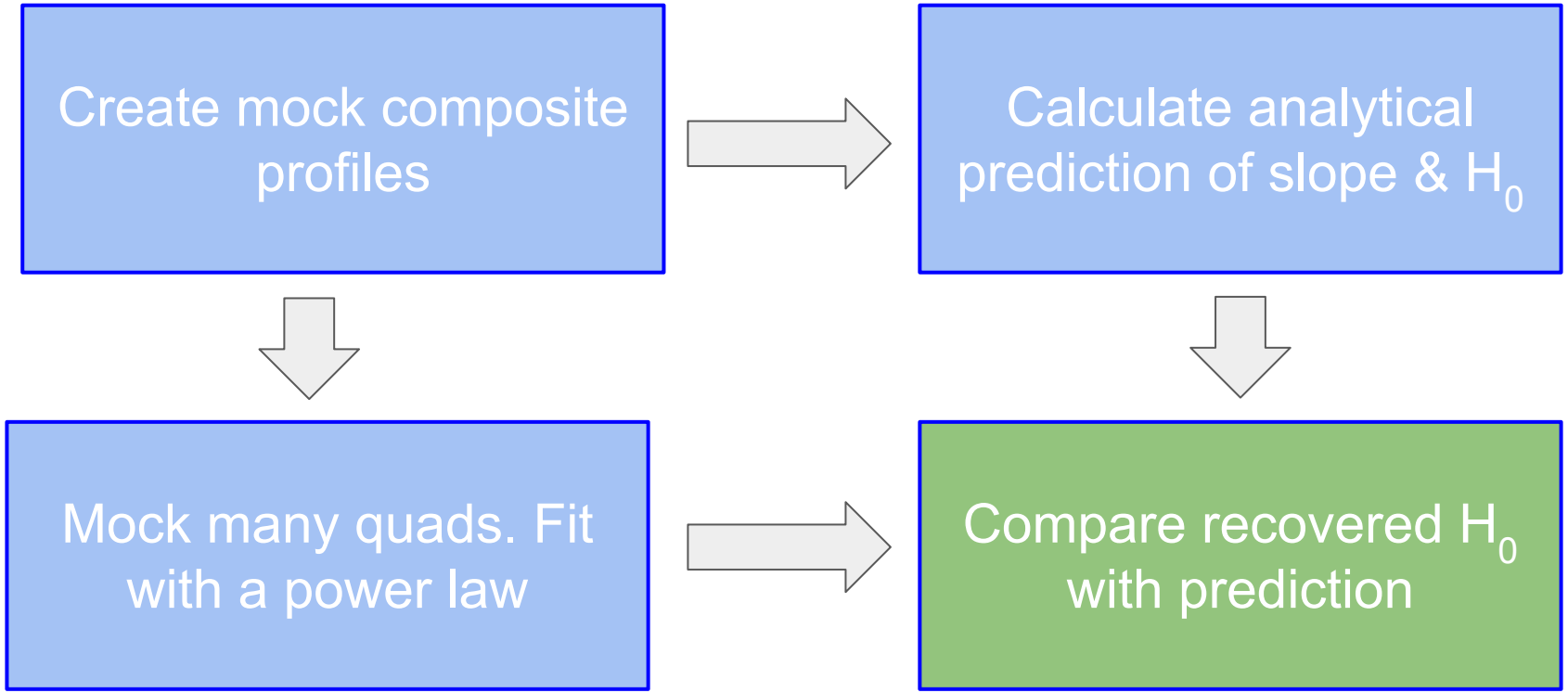
Motivation

How does this analytical prediction compare to the fitted value of H_0?

How accurately can one determine from a 1D profile what the recovered value of H_0 will be?

What will the role of stellar kinematics be?

Method

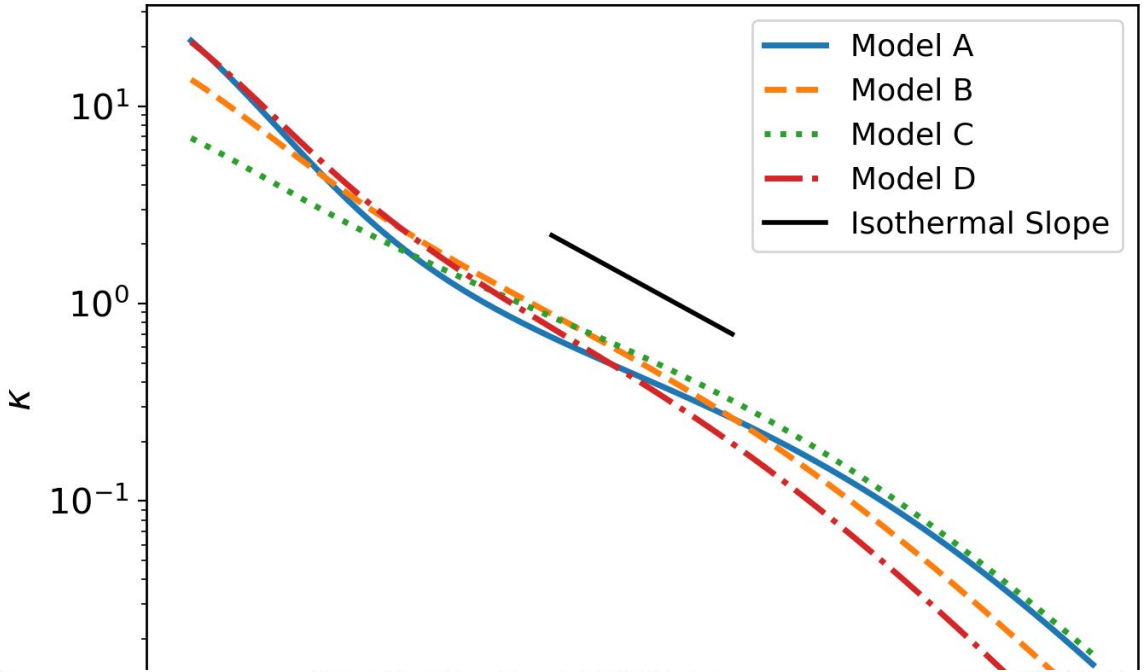

Create mock composite profiles
Calculate analytical prediction of slope & H_0
Mock many quads. Fit with a power law
Compare recovered H_0 with prediction

Model profiles

Two-component:

1. NFW component
2. Steeper power-law component

Resulting slopes near isothermal, $R_{Ein} \approx 5$kpc



	Profile construction parameters						Resulting lens physical attributes					MST values		
Model	α	b[kpc$^{2-\alpha}$]	r_s[kpc]	κ_s	R_E[kpc]	R_{trans}[kpc]	$\frac{\Sigma_{DM}}{\Sigma_{total}}\|_{R_E}$	M_{200}[M$_\odot$]	r_{200}[kpc]	c	$\langle\sigma^P\rangle$[km/s]	s	λ	s_λ
A	0.30	30.0	30.0	0.12	5.1	1.7	0.81	4.5×10^{12}	271	9.0	207	-0.830	1.06	-0.94
B	0.60	10.07	13.33	0.206	5.7	2.1	0.67	2.8×10^{12}	234	17.6	262	-1.03	0.925	-0.895
C	0.816	3.76	22.25	0.157	4.9	1.6	0.68	5.4×10^{12}	291	13.1	332	-0.815	0.904	-0.702
D	0.40	22.53	10.0	0.225	5.5	2.0	0.70	1.7×10^{12}	195	19.5	225	-1.14	0.960	-1.05

Fitting specifics

- 100 quads produced per model profile
- Image point source positions fit using `lensmodel`
- Very precise astrometry (0.003”) and time delay (0.1day) uncertainties

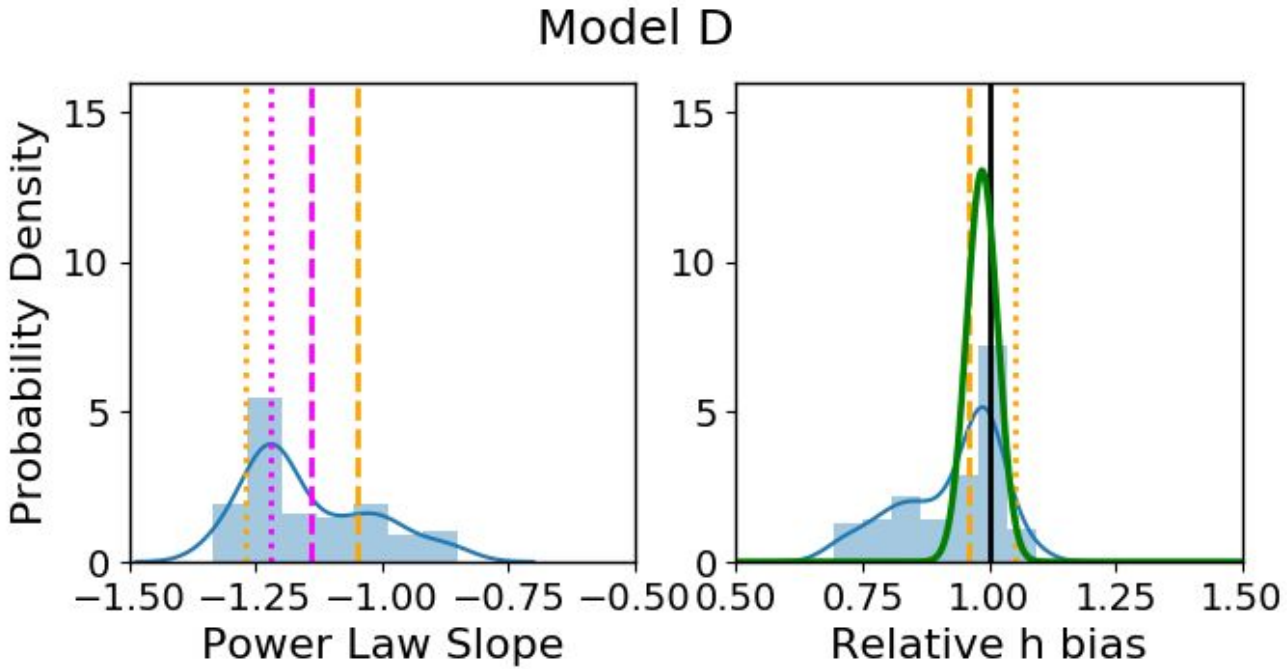
Each fit returns model parameters, χ^2, and H_0

- Nearly all (>97%) of quads fit with χ^2/dof <1
- Converting χ^2 to likelihood, MLE determines combined H_0 recovered value

Recovery

Distribution of recovered values

MLE combined estimate

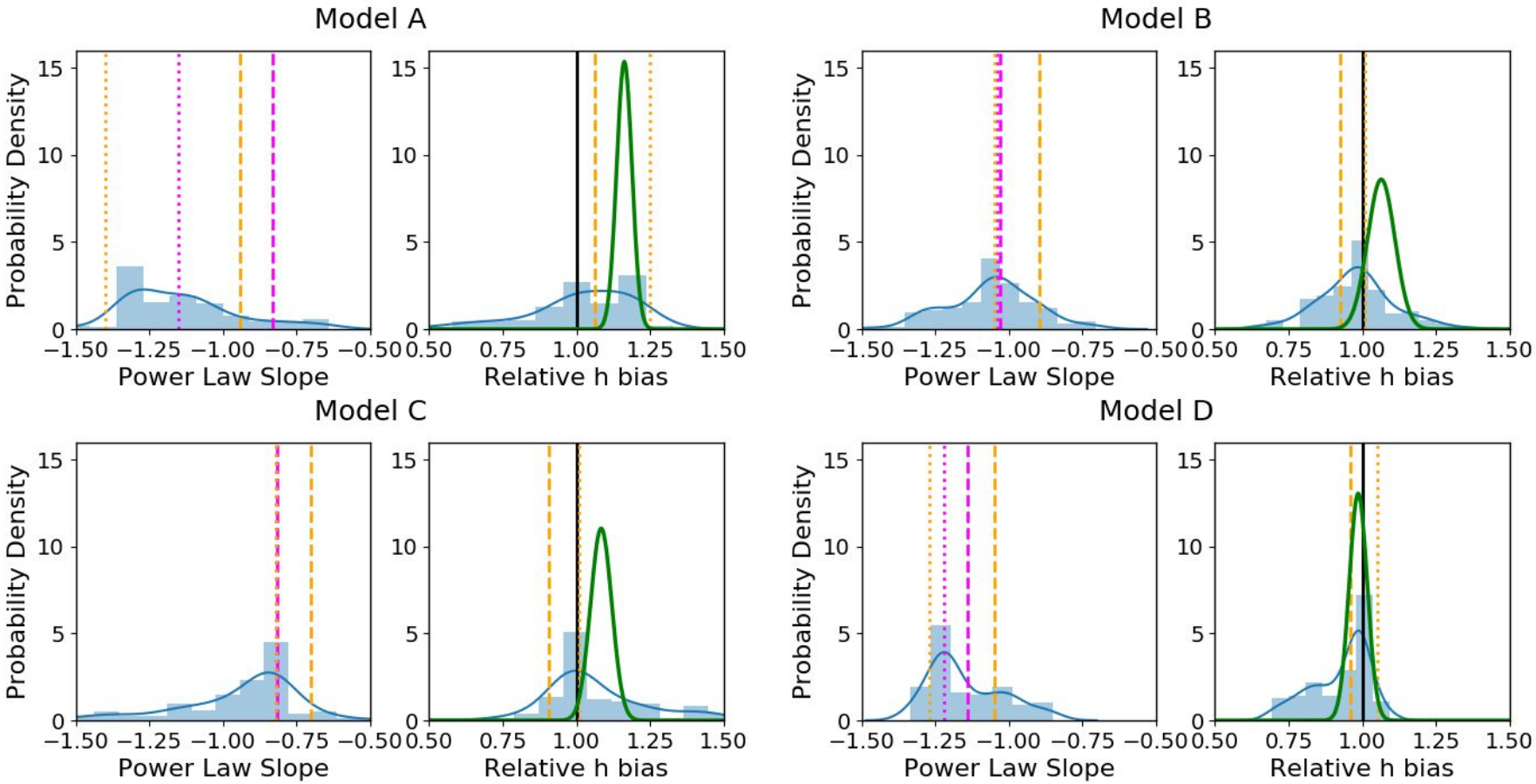


Local slope

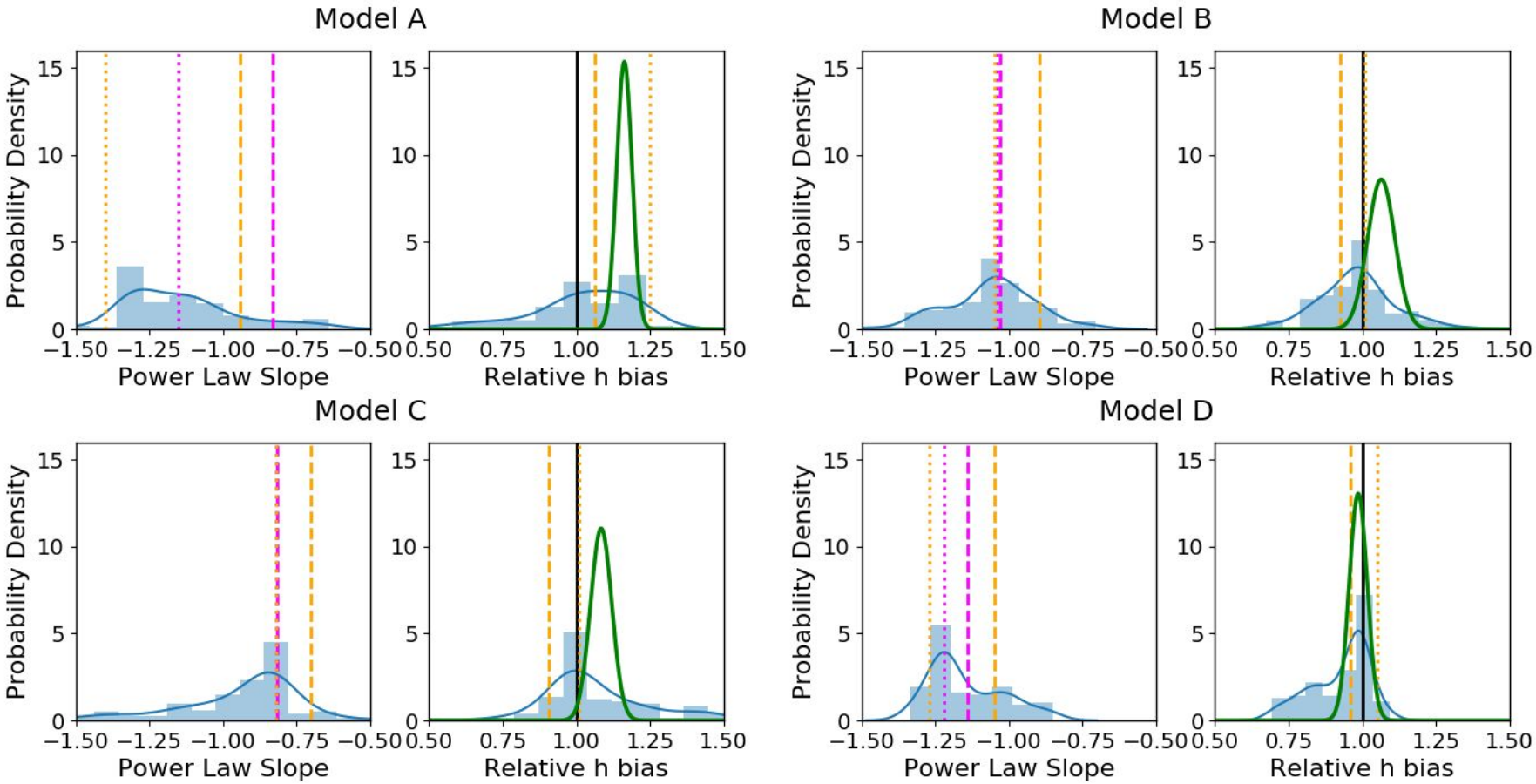
Using predicted λ

Slope after transformation

Dashed using κ, dotted using averaged κ

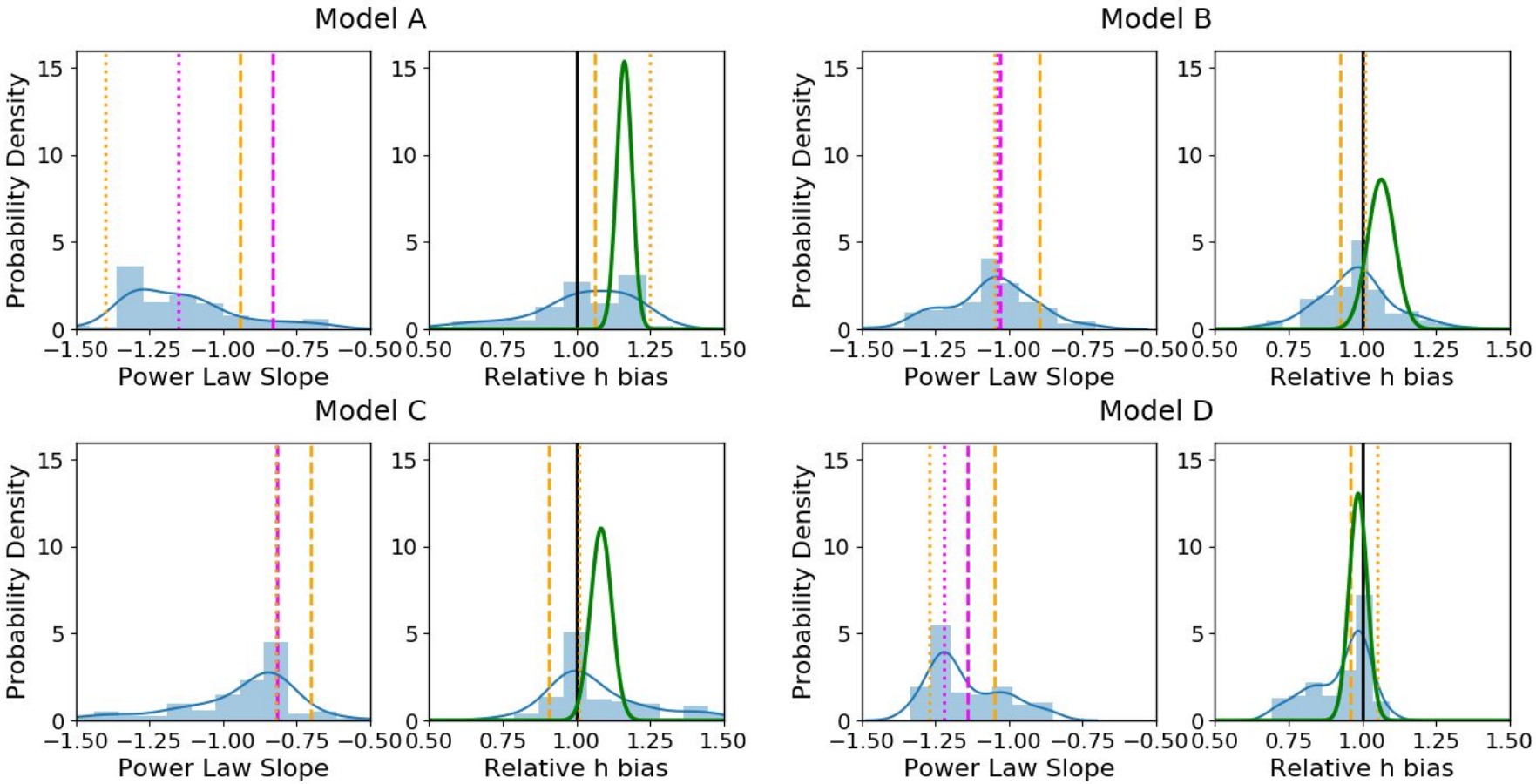


Gomer & Williams
2020



1. Spread of recovered values is extensive- MLE combination of many lenses helps

Gomer & Williams 2020



2. Bias is nonzero for most cases

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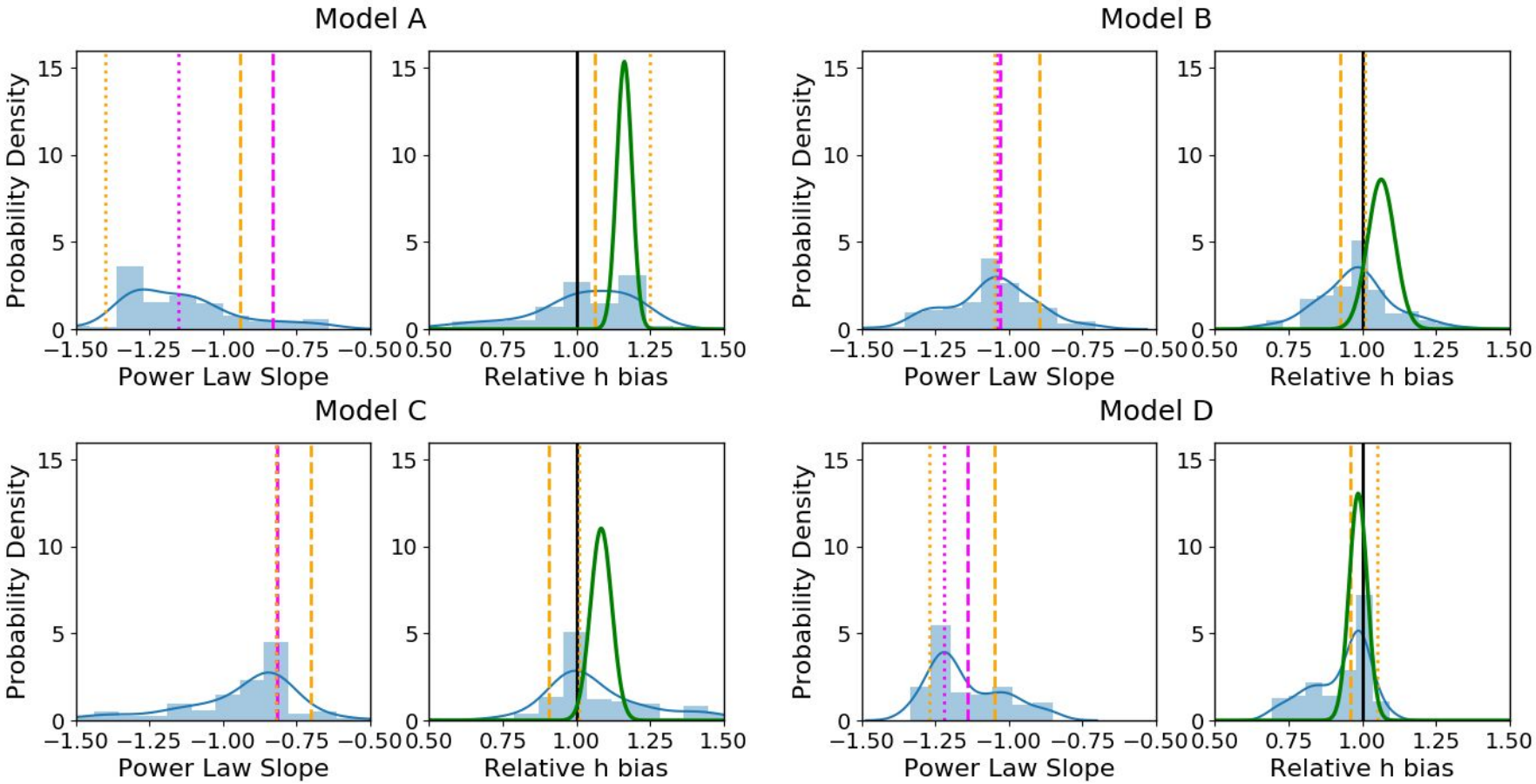
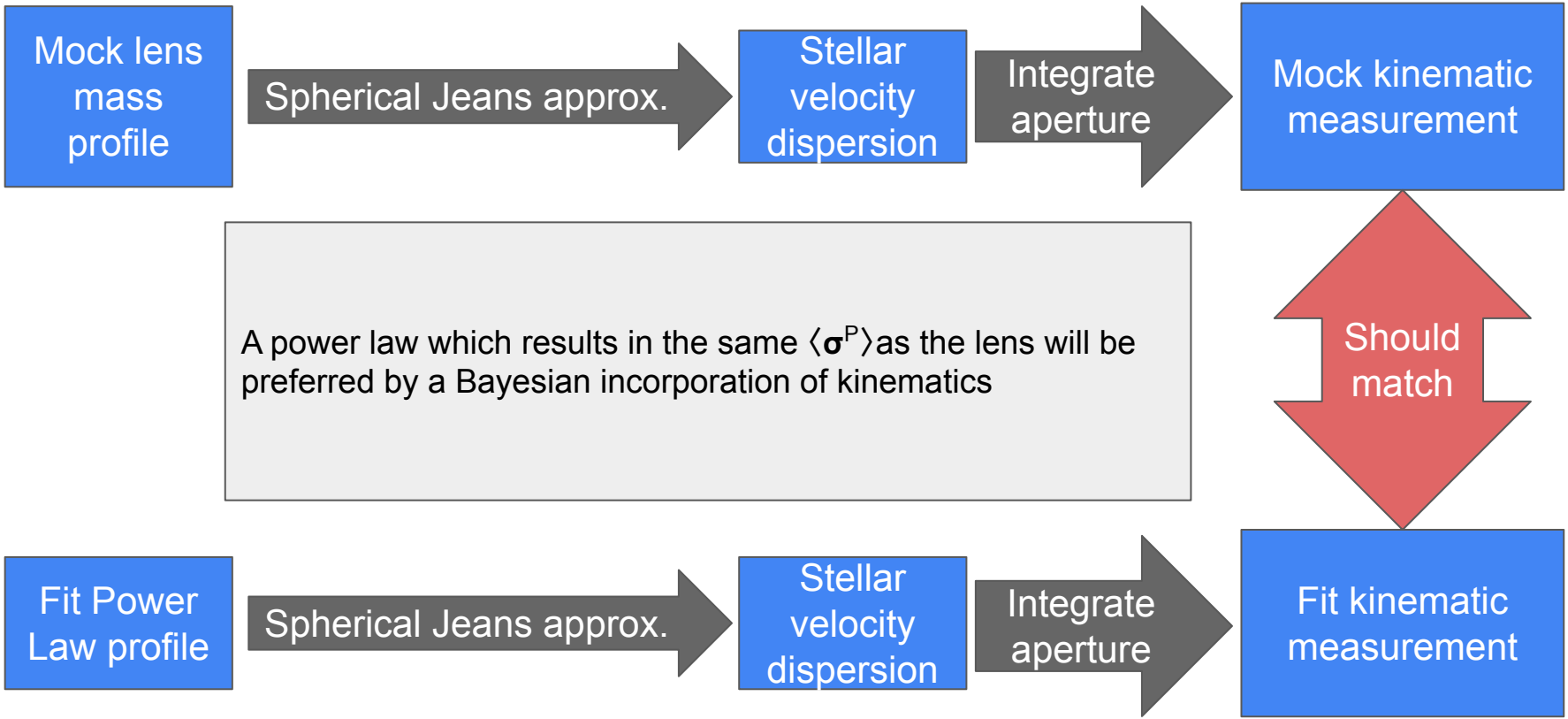


3. Neither slope nor H_0 match the analytical prediction. Often worse than null hypothesis.

Gomer & Williams 2020

Inclusion of kinematic information



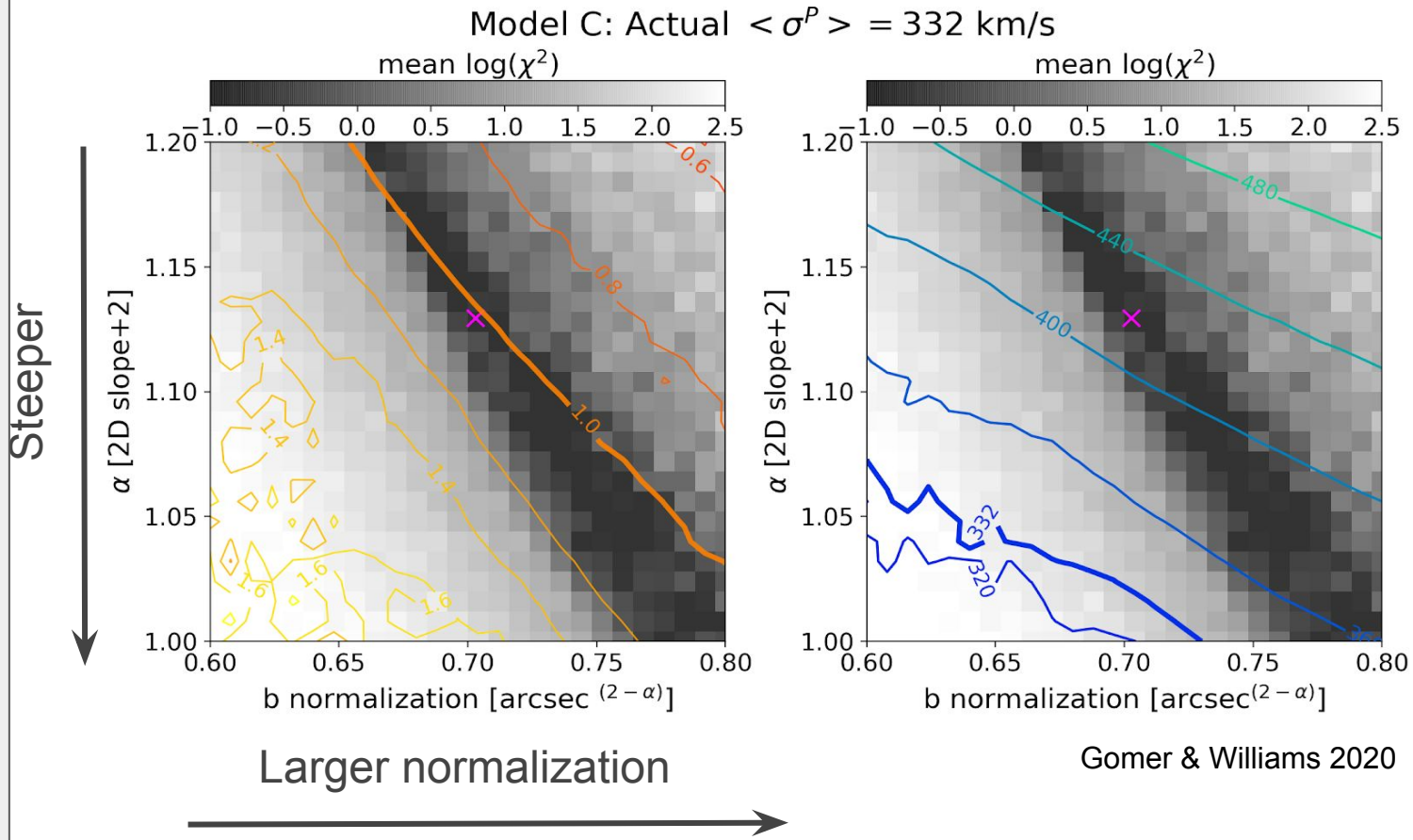
Main features:

1. gray=good fits (**MSD**)

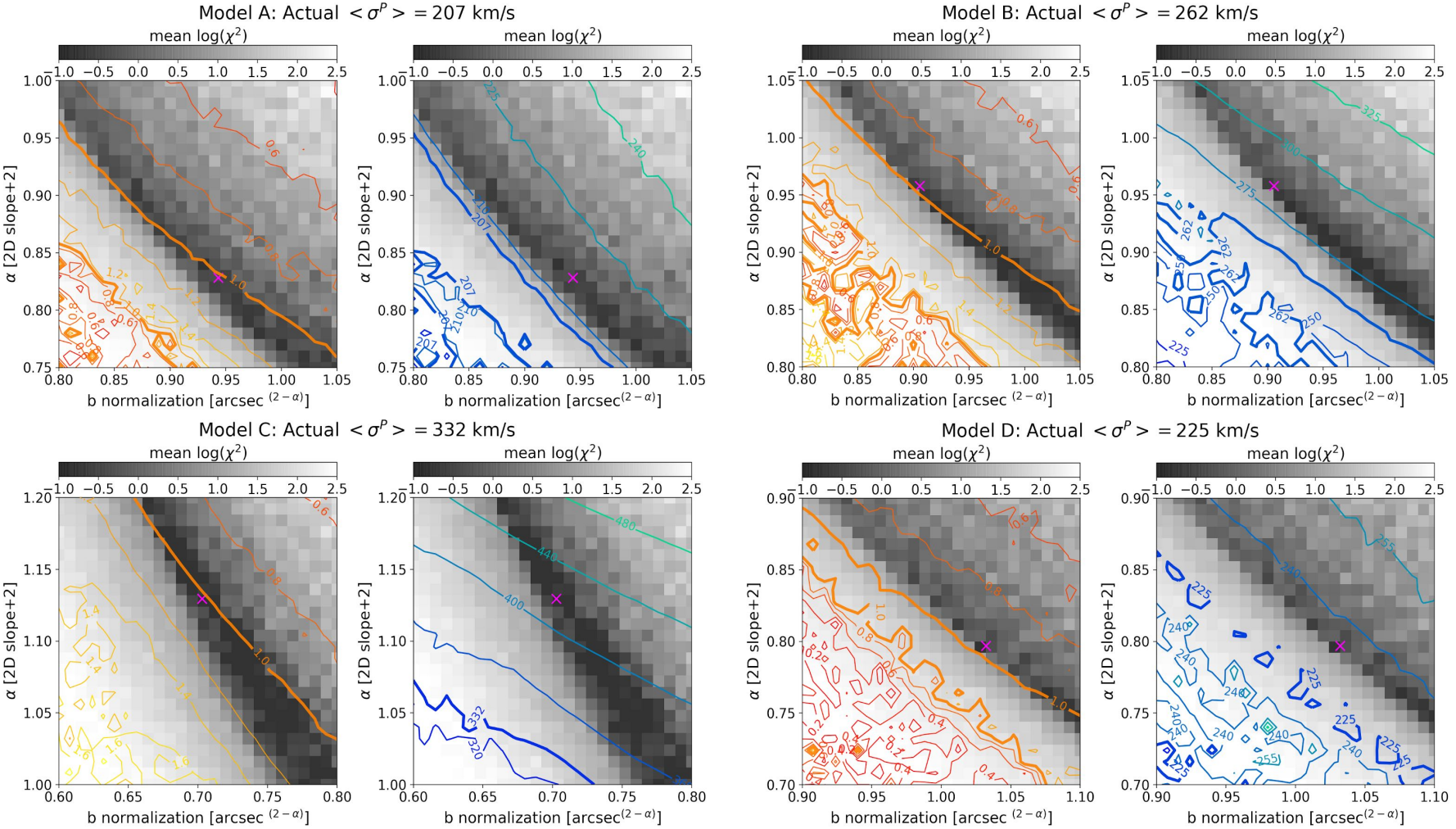
2. **Thick blue line** where consistent with kinematics

3. **Thick orange line** where unbiased H_0.

Orange not consistent with **blue**!



Gomer & Williams 2020



Gomer & Williams 2020

What can we conclude?

Because

1. the only difference between model and “observed” kinematics is power law model vs. composite “real” lens, and
2. the inferred model which matches these kinematics is not consistent with unbiased H_0,

we must conclude that the inclusion of kinematic information can introduce a bias if the mass model type is not perfectly known

Limitations & Future Work

- Only 4 model profiles- may not generalize to actual population of galaxies
- Simple fitting
  - no extended ring

Confirmation of this result is required using a more representative lens population and/or more sophisticated fitting procedures

Main conclusions

1. An analytical estimation of $\boldsymbol{\lambda}$ from a 1D profile shape does not match the H_0 bias from fitting mock quads.

2. Stellar kinematic constraints break the MSD, but not necessarily in an unbiased way. It is possible that in some cases kinematics can introduce bias.