Testing Cosmological Models with Galaxy Surveys

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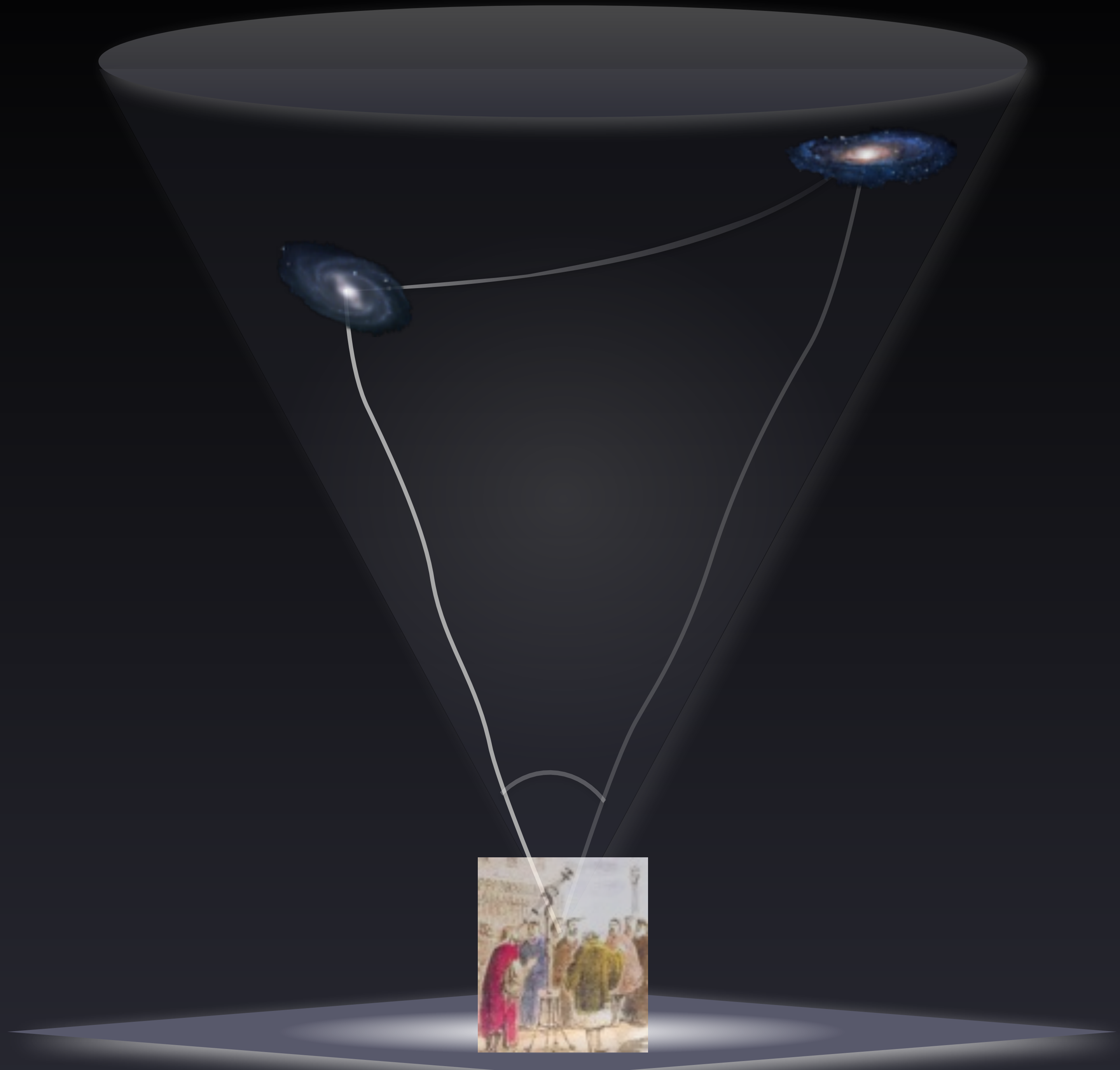
with M. Kamionkowski, A. Szalay

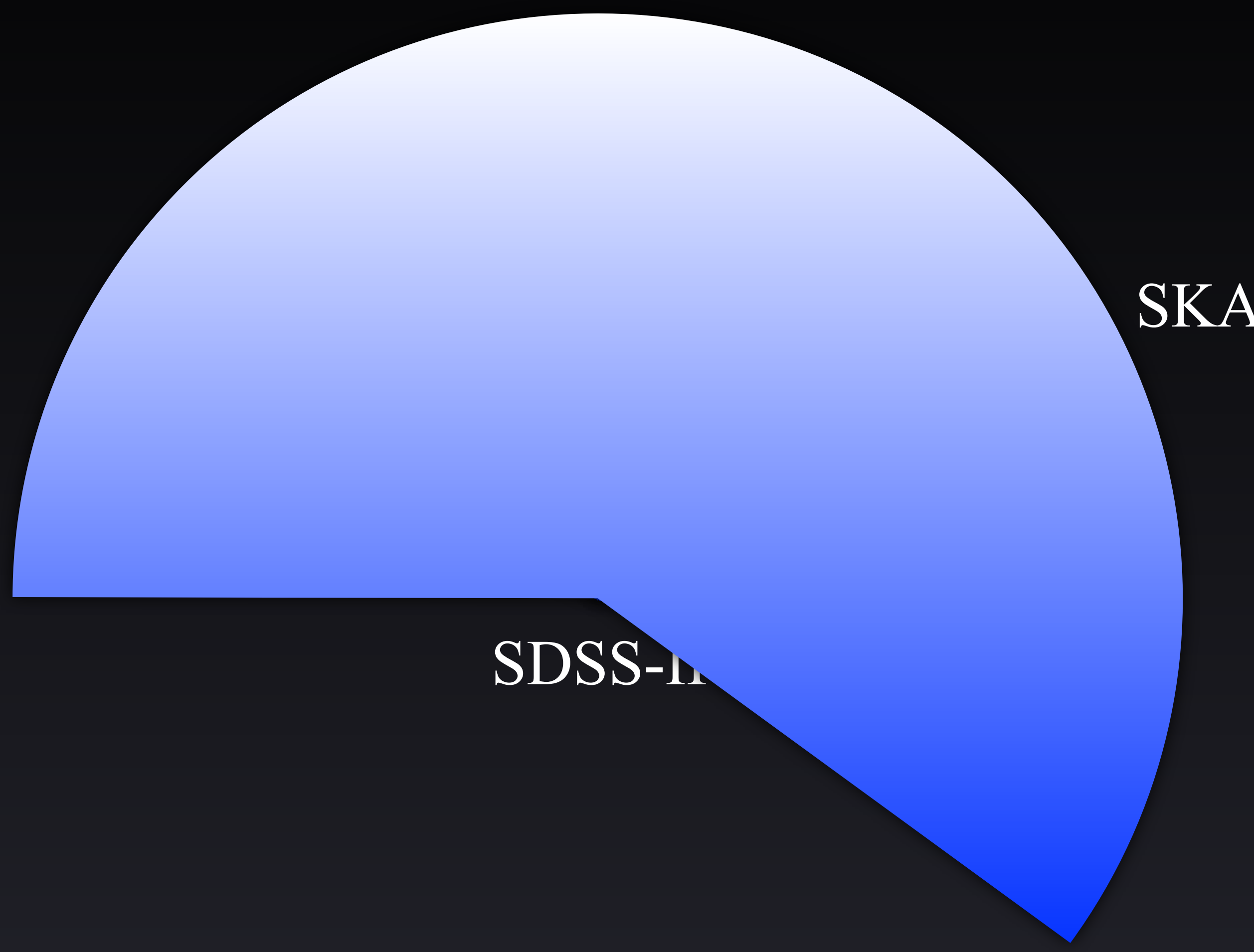
Outline

Boring part

Fun part



Future surveys



We are going to probe much larger volumes in the next few years

Future surveys

We need a very precise theoretical modeling

Precision of data will improve

Possible to test more exotic models

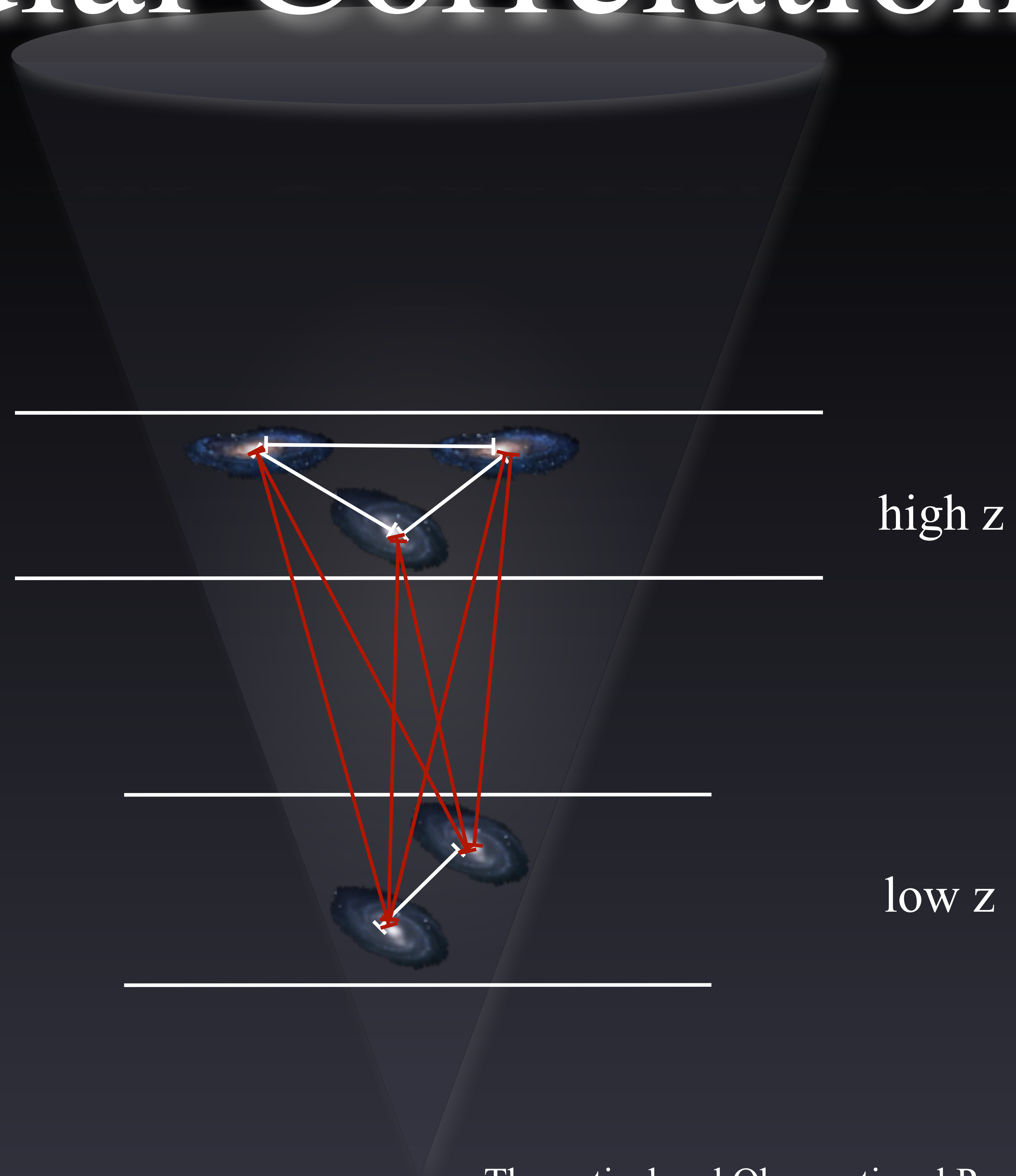
Observed galaxy correlation

$$\Delta = \delta + \mathrm{RSD}(+\,\kappa + \mathrm{pot}\,)$$

$$\xi^{obs} = \sum_{XY} \langle XY \rangle$$

naming issue:
relativistic corrections,
magnification bias,
unified rsd+lensing, …

Radial Correlations



$\langle \delta\kappa \rangle$

Observed galaxy correlation

Antisymmetric galaxy cross-correlations

Dai et al., today

Antisymmetric galaxy cross-correlations as a cosmological probe

Liang Dai[1], Marc Kamionkowski[1], Ely D. Kovetz[1], Alvise Raccanelli[1], and Maresuke Shiraishi[2]
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(Dated: July 19, 2015)

The auto-correlation between two members of a galaxy population is symmetric under the interchange of the two galaxies being correlated. The *cross*-correlation between two different types of galaxies, separated by a vector $\mathbf{r}$, is not necessarily the same as that for a pair separated by $-\mathbf{r}$. Local anisotropies in the two-point cross-correlation function may thus indicate a specific direction which when mapped as a function of position trace out a vector field. This vector field can then be decomposed into longitudinal and transverse components, and those transverse components written as positive- and negative-helicity components. A locally asymmetric cross-correlation of the longitudinal type arises naturally in halo clustering, even with Gaussian initial conditions, and could be enhanced with local-type non-Gaussianity. Early-Universe scenarios that introduce a vector field may also give rise to such effects. These antisymmetric cross-correlations also provide a new possibility to seek a preferred cosmic direction correlated with the hemispherical power asymmetry in the cosmic microwave background and to seek a preferred location associated with the CMB cold spot. New ways to seek cosmic parity breaking are also possible.

preferred cosmic direction

Cosmological tests

Gravity

non-Gaussianity

Dark Energy

Dark Matter

Dark Matter

Cold Dark Matter

Self-Interacting?

"Dark atoms"?

Dark Matter

NATURE | NEWS

Did dark matter kill the dinosaurs?

The Solar System's periodic passage through a 'dark disk' on the galactic plane could trigger comet bombardments that would cause mass extinctions.

Elizabeth Gibney

07 March 2014

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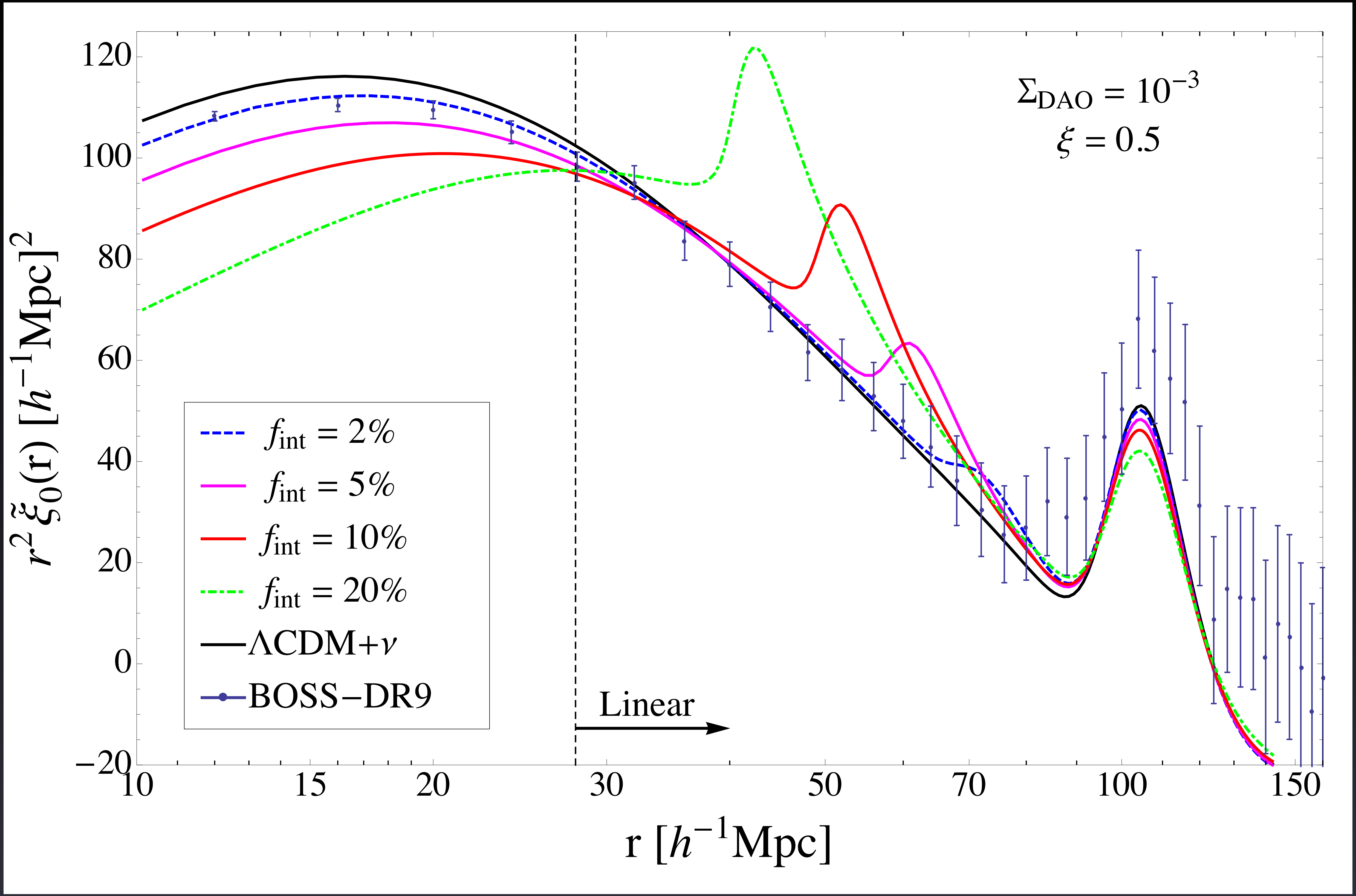
Mark Stevenson/Stocktrek Images/Corbis

Mass extinctions such as the one that wiped out the dinosaurs seem to happen with regularity, pointing to possible cosmic causes.

Dark Matter

PIDM



Cyr-Racine et al., 2013

Dark Matter

Did Dark Matter Kill the Dinosaurs? Probably Not. But It's a Fun idea.

By Phil Plait

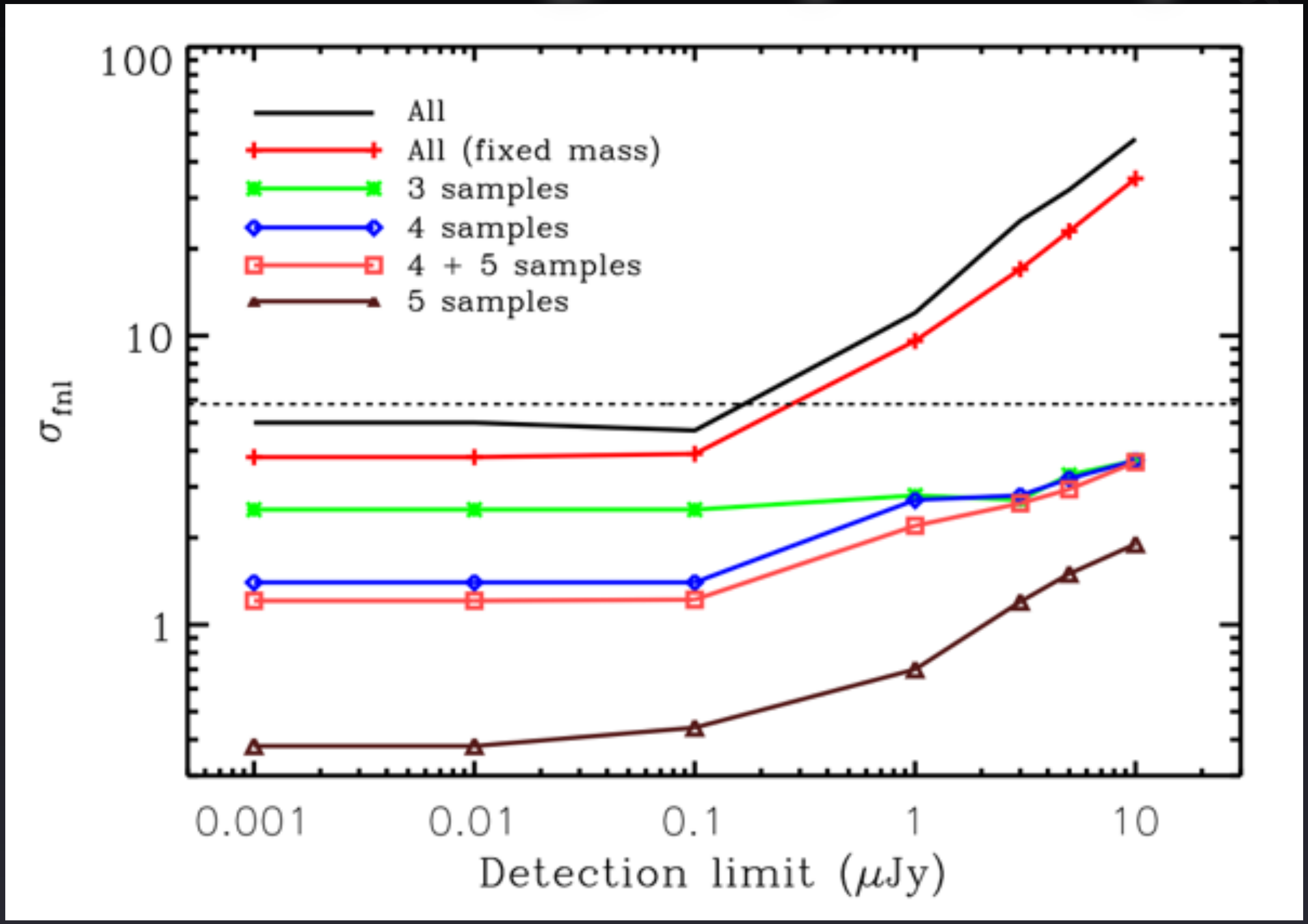
128 82

Dark Matter

More to come:
stay tuned

non-Gaussianity

SKA HI galaxy survey



Camera et al., 2014

non-Gaussianity

primordial vector fields

(other shapes)

Shape	$\mathrm{EMU}_C^{100\mu Jy}$	$\mathrm{EMU}_O^{100\mu Jy}$	$\mathrm{EMU}_C^{50\mu Jy}$	$\mathrm{EMU}_O^{50\mu Jy}$	$\mathrm{SKA}_C^{5\mu Jy}$	$\mathrm{SKA}_O^{5\mu Jy}$	SKA_C^{100nJy}	SKA_O^{100nJy}	Futuristic	CMB
$\sigma(f_{\mathrm{NL}})$ local	11.94	5.54	9.26	4.37	1.62	1.06	0.67	0.51	0.21	5.7
$\sigma(f_{\mathrm{NL}})$ equilateral	221.14	79.84	179.03	62.58	22.24	9.09	6.18	2.83	0.42	70
$\sigma(f_{\mathrm{NL}})$ orthogonal	102.97	39.04	82.25	30.69	15.30	7.40	6.71	3.35	0.54	33
$\sigma(f_{\mathrm{NL}})$ folded	151.48	56.45	121.50	44.35	20.29	9.25	8.15	4.14	0.96	65
$\sigma(c_{L=1})$	1916.29	721.15	1519.8	558.35	200.62	78.32	41.81	17.54	2.14	103
$\sigma(c_{L=2})$	10874.9	4113.82	8436.7	2952.5	1098.93	393.60	193.48	76.55	9.22	26

A. Raccanelli, et al., today

radio continuum + some redshift information

(e.g. B. Menard's group works)

String Axiverse

Quintessence?

Requires flat potential

ok if quintessence field is an axion-like field

Still fine-tuning problems

Potentially solved by string-axiverse

“why now” problem

helps with fine tuning

Kamionkowski et al., 2014

String Axiverse

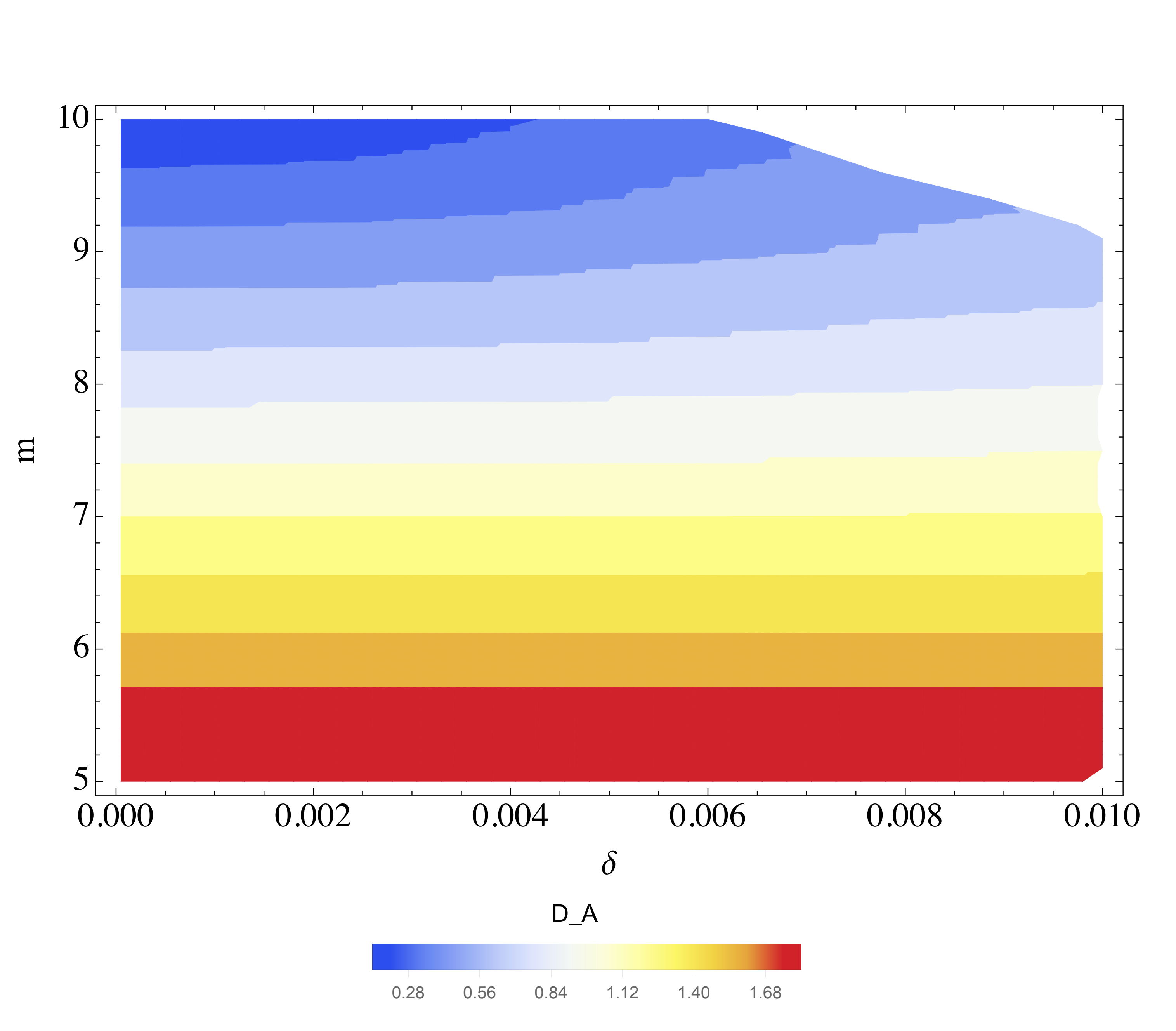
Cosmological constraints to an axiverse-inspired quintessence field

Razieh Emami[1,2], Daniel Grin[3], Marc Kamionkowski[2], Josef Pradler[4], and Alvise Raccanelli[2]

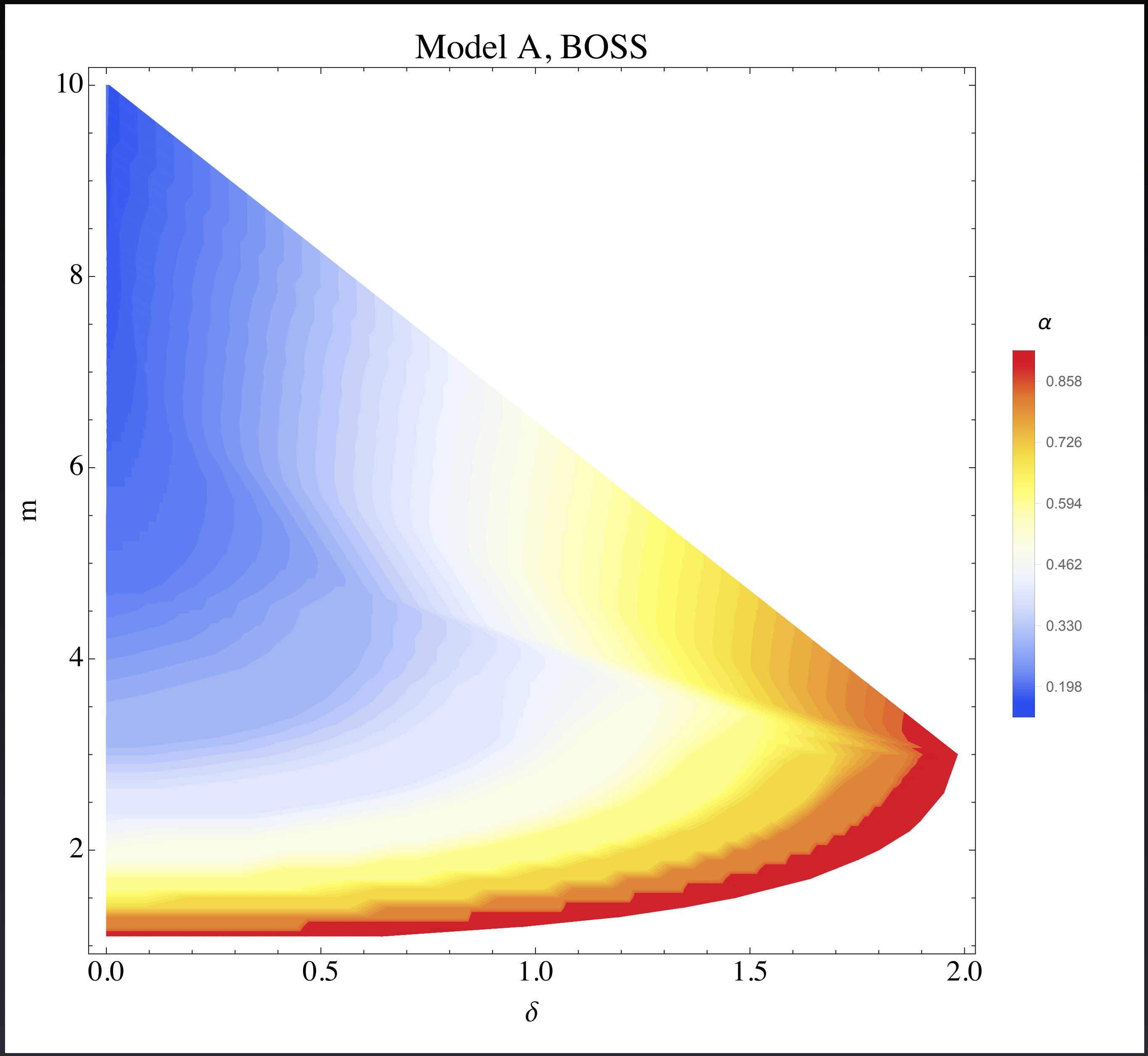
It was recently suggested that accelerated cosmic expansion might be driven by an axion-like quintessence field with a sub-Planckian decay constant, an idea inspired by the string axiverse. The scenario requires that the axion field be initially very near the maximum of its potential. The model is parametrized by an axion decay constant $f = \alpha M_p$, with $\alpha \sim 0.1$ and $M_{\rm pl}$ the reduced Planck mass, and with an axion mass m_a and an initial misalignment angle $|\theta_i|$, which is taken to be close to π. Here this parameter space is mapped onto the parameter space of the dark-energy density $\Omega_{\rm de}$, equation-of-state parameter w, and the equation-of-state time-evolution parameter w_a, in order to determine they m_a and θ_i values consistent with axion dark energy today. Current cosmological data (measurements of the baryon acoustic oscillation scale and *Planck* measurements of CMB temperature anisotropies) are then used to constrain this parameter space and thus the α-m-θ_i parameter space.

$$V(\phi) = \Lambda^4 \left[1 - cos(\phi/f)\right]$$

String Axiverse



String Axiverse



Dark matter density from axion misalignment

D. Walker, B. Horn, A. Raccanelli,
M. Kamionkowski, D. Spergel

string theory scenario in which dark matter is made by a multitude of axions

axions decay into smaller mass axions

Mass

Constraints on decay ratio

Power spectrum

Satellite galaxies

Strong lensing

Conclusions

Future surveys will be very powerful

Boring (but necessary) part:

Test "standard" parameters

More precise modeling (large and small scales)

Fun (and potentially high-reward) part:

Test exotic models

PT, Simulations, EFT are all great

Thank You