OTÁVIO ALVES
MASTER'S STUDENT AT IFT-UNESP
ADVISED BY ROGÉRIO ROSENFELD

Probing Dark Matter properties using photometric surveys

Otávio Alves, Felipe Oliveira, Isaac Tutusaus,
Rogério Rosenfeld, Vivian Miranda

IFT - UNESP

CNPq

LIneA

DARK ENERGY SURVEY

INTRO

What is Dark Matter?

INTRO

What is Dark Matter?

I don't know!

Maybe a pressureless perfect fluid.

INTRO

What is Dark Matter?

I don't know!

Maybe a pressureless perfect fluid.

Really?

GENERALIZED DARK MATTER

$$T_{\mu\nu} = (\rho + p)u_\mu u_\nu + p g_{\mu\nu} + \Pi_{\mu\nu}$$

GENERALIZED DARK MATTER

$$T_{\mu\nu} = (\rho + p)u_\mu u_\nu + p g_{\mu\nu} + \Pi_{\mu\nu}$$

$$\bar{p} = w(k,z)\bar{\rho}$$

$$\frac{\delta p}{\bar{\rho}} = c_a^2 \delta + \left[c_s^2(k,z) - c_a^2\right] \delta_{\rm rest}$$

$$\dot{\sigma} = -3\mathcal{H}\sigma + \frac{4}{1+w} c_{vis}^2(k,z)\hat{\Theta}$$

GENERALIZED DARK MATTER

$$T_{\mu\nu} = (\rho + p)u_\mu u_\nu + p g_{\mu\nu} + \Pi_{\mu\nu}$$

$$\bar{p} = w(k,z)\bar{\rho}$$

$$\frac{\delta p}{\bar{\rho}} = c_a^2 \delta + \left[c_s^2(k,z) - c_a^2\right] \delta_{\rm rest}$$

$$\dot{\sigma} = -3\mathcal{H}\sigma + \frac{4}{1+w} c_{vis}^2(k,z)\hat{\Theta}$$

$$\dot{\delta} = 3\mathcal{H}(w\delta - \frac{\delta p}{\bar{\rho}}) - (1+w)(\frac{\dot{h}}{2} + k^2\theta)$$

$$\dot{\theta} = (3c_a^2 - 1)\mathcal{H}\theta + \frac{\delta p}{\bar{\rho}} \frac{1}{1+w} - \frac{2}{3}k^2\sigma$$

GENERALIZED DARK MATTER

$$T_{\mu\nu} = (\rho + p)u_\mu u_\nu + p g_{\mu\nu} + \Pi_{\mu\nu}$$

$$\bar{p} = w(k,z)\bar{\rho}$$

$$\frac{\delta p}{\bar{\rho}} = c_a^2 \delta + \left[c_s^2(k,z) - c_a^2\right] \delta_{\rm rest}$$

$$\dot{\sigma} = -3\mathcal{H}\sigma + \frac{4}{1+w} c_{vis}^2(k,z)\hat{\Theta}$$

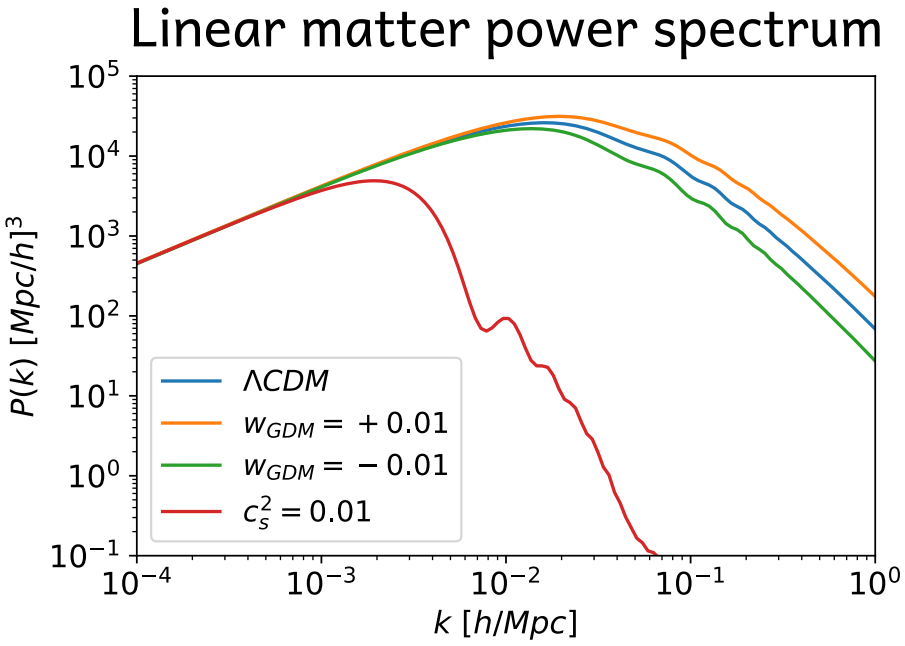
$$\dot{\delta} = 3\mathcal{H}(w\delta - \frac{\delta p}{\bar{\rho}}) - (1+w)(\frac{\dot{h}}{2} + k^2\theta)$$

$$\dot{\theta} = (3c_a^2 - 1)\mathcal{H}\theta + \frac{\delta p}{\bar{\rho}} \frac{1}{1+w} - \frac{2}{3}k^2\sigma$$

Implemented on CLASS

GENERALIZED DARK MATTER

Focusing on w, c_s^2



w shift on the matter-radiation equality time

c_s^2 suppression of power at small scales

GENERALIZED DARK MATTER

Wayne Hu
Structure Formation with Generalized Dark Matter (astro-ph/9801234)

Daniel B. Thomas, Michael Kopp, Constantinos Skordis
Constraining dark matter properties with CMB observations (1601.05097)

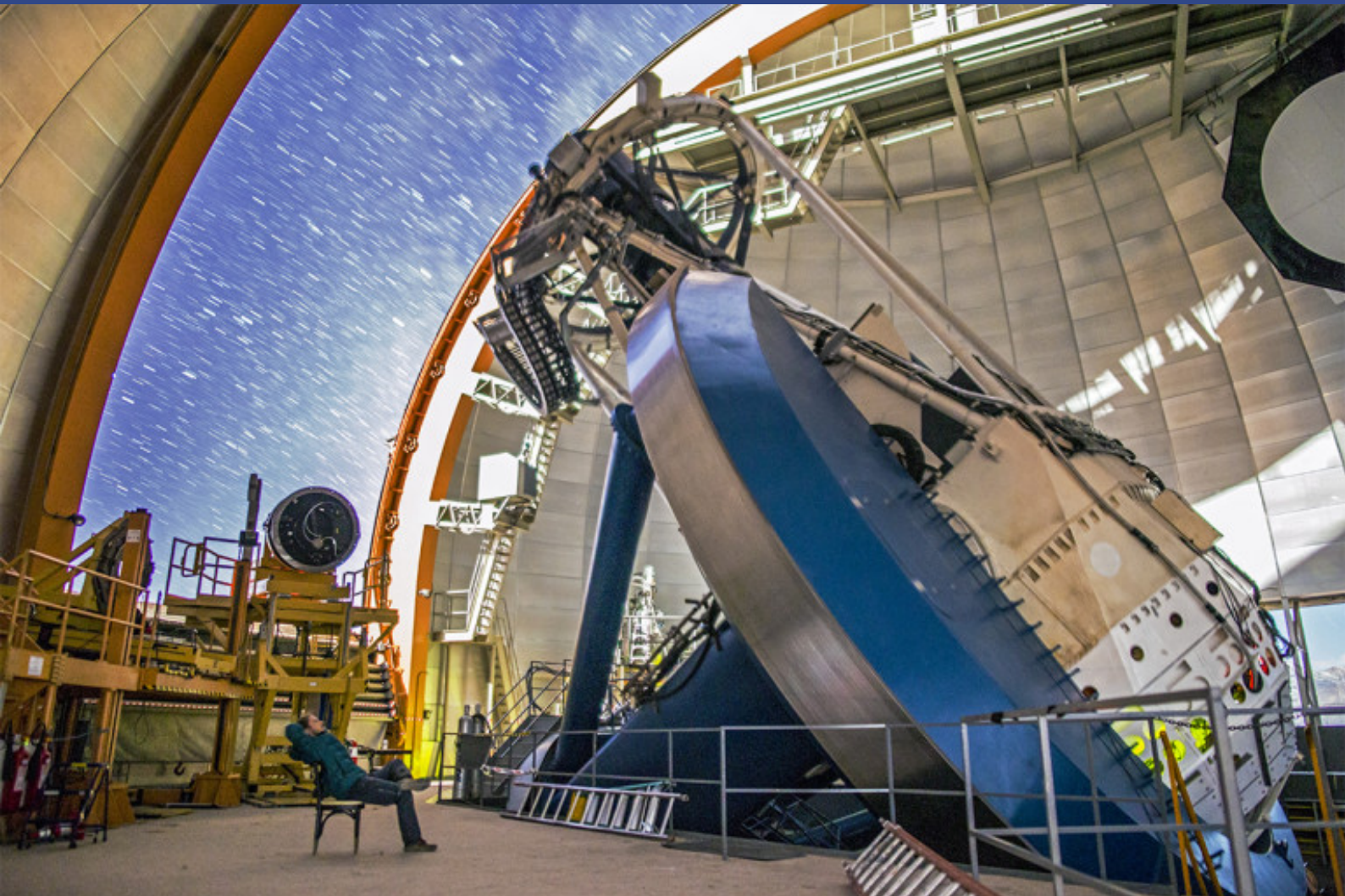
Michael Kopp, Constantinos Skordis, Daniel B. Thomas, Stéphane Ilić
The Dark Matter equation of state through cosmic history (1802.09541)

Isaac Tutusaus, Brahim Lamine, Alain Blanchard
Generalized Dark Matter model with the Euclid satellite (1805.06202)

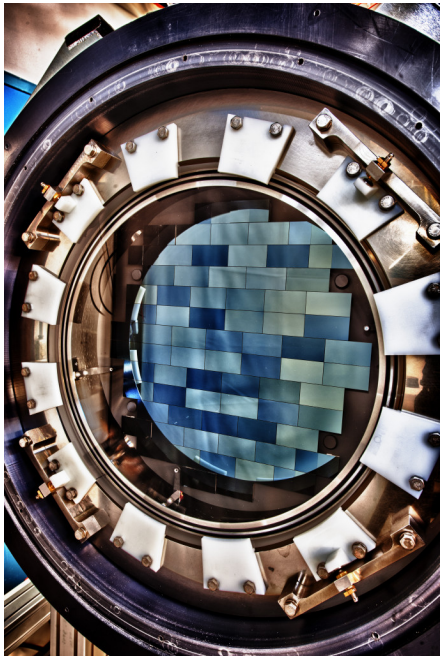
Suresh Kumar, Rafael C. Nunes, Santosh Kumar Yadav
Testing the warmness of dark matter (1901.07549)

Daniel B. Thomas, Michael Kopp, Katarina Markovič
Using LSS data and a halo model to constrain GDM (1905.02739)

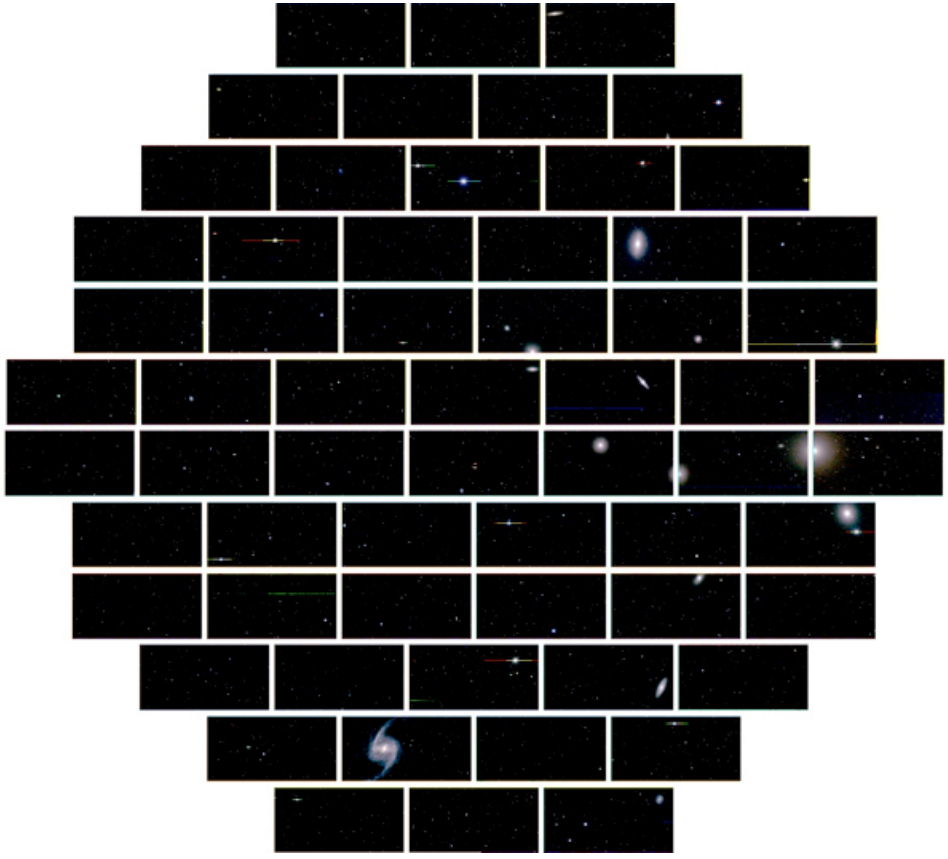
THE DARK ENERGY SURVEY



DECAM

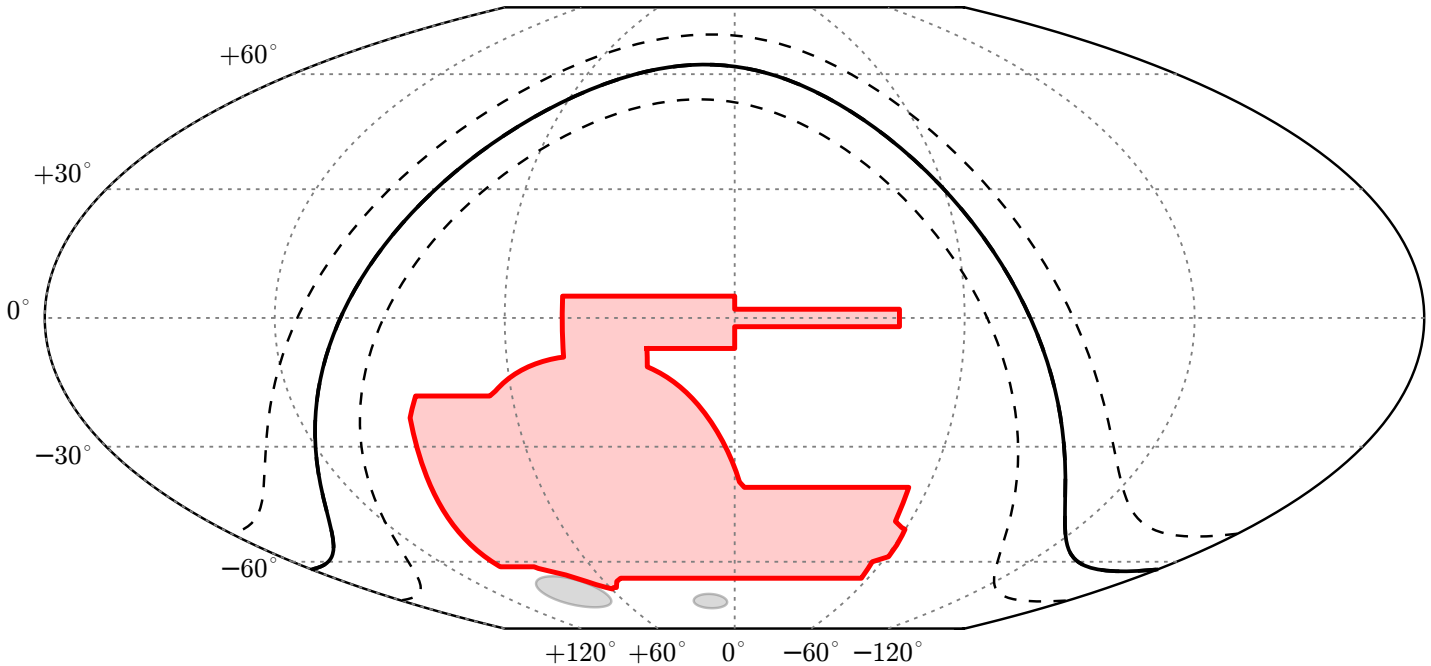


570 MP



THE DARK ENERGY SURVEY

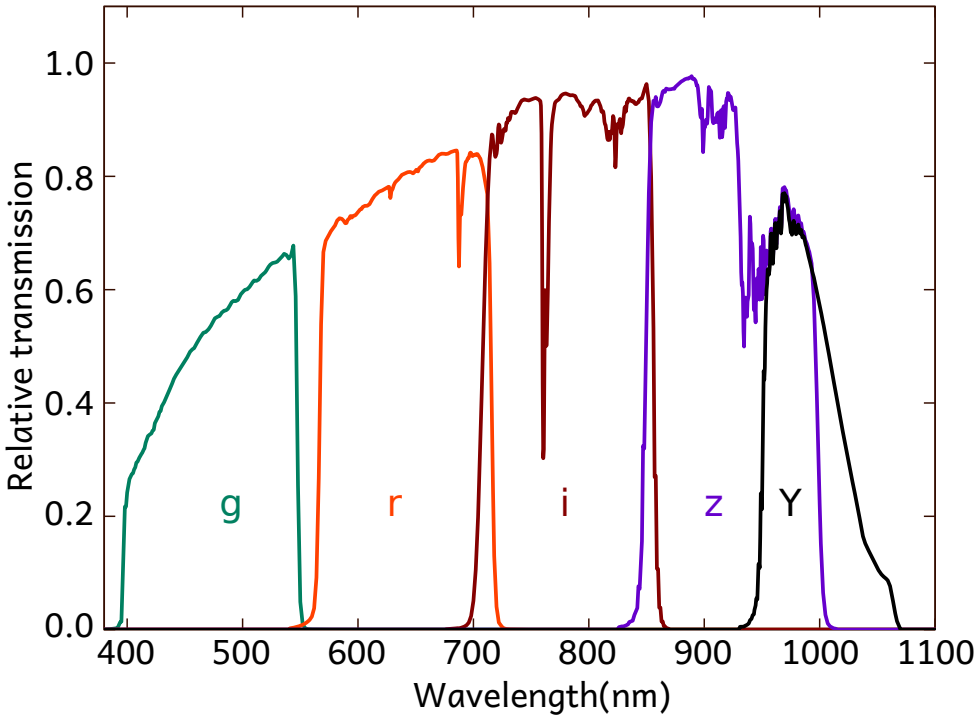
$$f_{sky} = 1/8$$



The Dark Energy Survey Data Release 1, 1801.03181

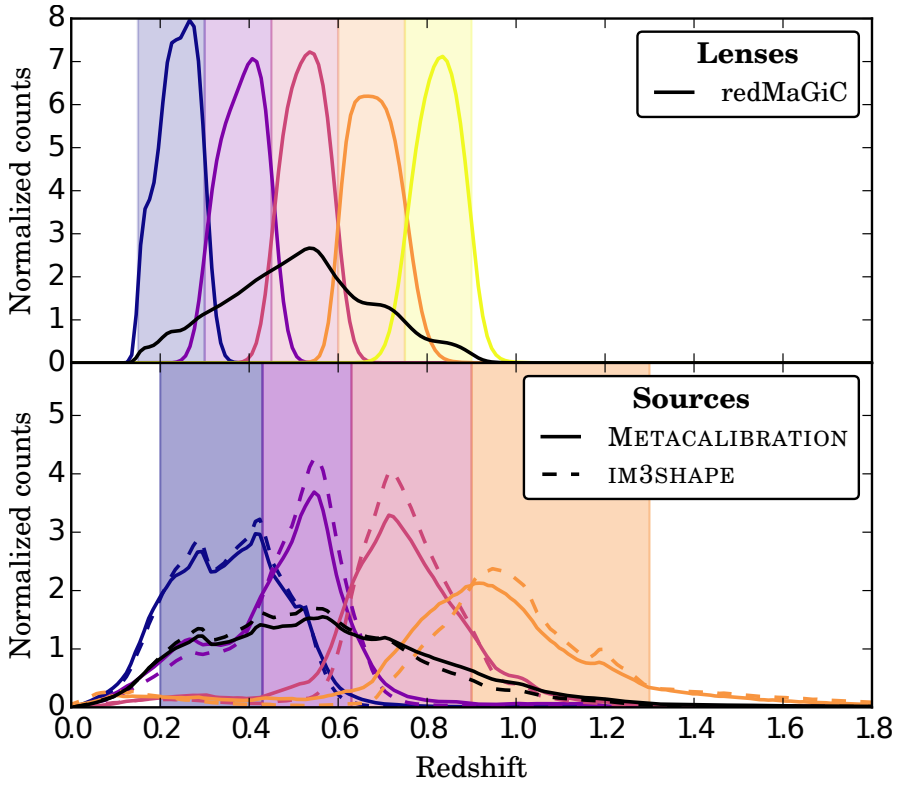
PHOTOMETRIC REDSHIFT

Instead of measuring spectra, we take images in 5 different optical/near infra-red filters.



The Dark Energy Survey Data Release 1, 1801.03181

PHOTOMETRIC REDSHIFT



DES Y1 Results: Cosmological Constraints from Galaxy Clustering and Weak Lensing (1708.01530)

3X2PT CORRELATION FUNCTIONS

$$C^{ij}_{\kappa\kappa}(l) = \int d\chi \frac{q^i_\kappa(\chi) q^j_\kappa(\chi)}{\chi^2} P\left(\frac{l+1/2}{\chi}, z(\chi)\right)$$

$$C^{ij}_{\delta\kappa}(l) = \int d\chi \frac{q^i_\delta\left(\frac{l+1/2}{\chi}, \chi\right) q^j_\kappa(\chi)}{\chi^2} P\left(\frac{l+1/2}{\chi}, z(\chi)\right)$$

$$C^{ij}_{\delta\delta}(l) = \int d\chi \frac{q^i_\delta\left(\frac{l+1/2}{\chi}, \chi\right) q^j_\delta\left(\frac{l+1/2}{\chi}, \chi\right)}{\chi^2} P\left(\frac{l+1/2}{\chi}, z(\chi)\right)$$

$$q^i_\delta(k, \chi) = b^i\left(k, z(\chi)\right) \frac{n^i_g(z(\chi))}{\bar{n}^i_g} \frac{dz}{d\chi}$$

$$q^i_\kappa(\chi) = \frac{3H_0^2\Omega_m}{2c^2} \frac{\chi}{a(\chi)} \int_\chi^{\chi_h} d\chi' \frac{dz}{d\chi'} \frac{n^i_\kappa(z(\chi'))}{\bar{n}^i_\kappa} \frac{\chi'-\chi}{\chi'}$$

Krause et al., DES Y1 Results: Multi-Probe Methodology and Simulated Likelihood Analyses, 1706.09359.

3X2PT CORRELATION FUNCTIONS

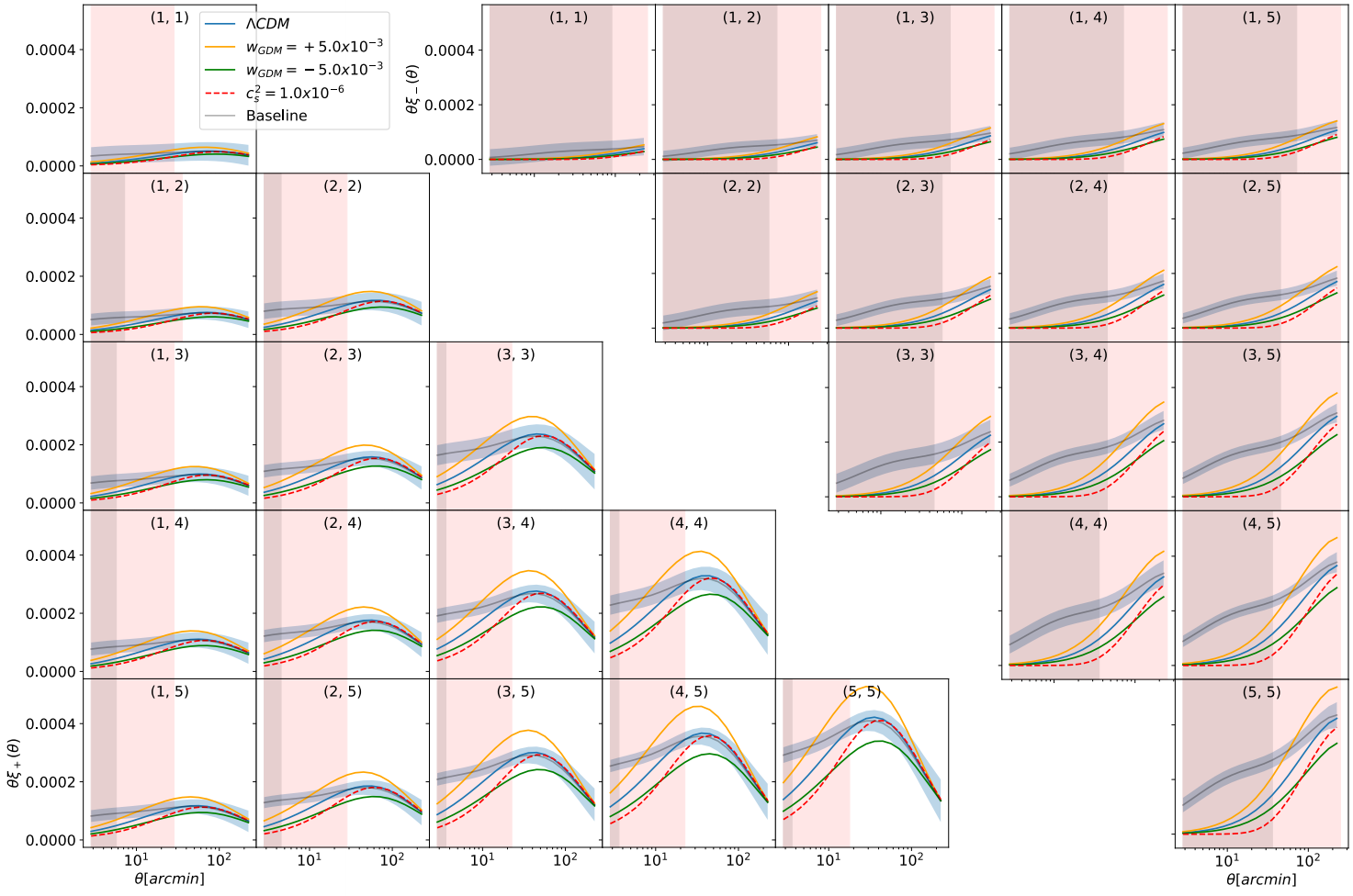
$$\xi^{ij}_{+/-}(\theta) = \int \frac{dl\, l}{2\pi} J_{0/4}(l\theta) C^{ij}_{\kappa\kappa}(l)$$

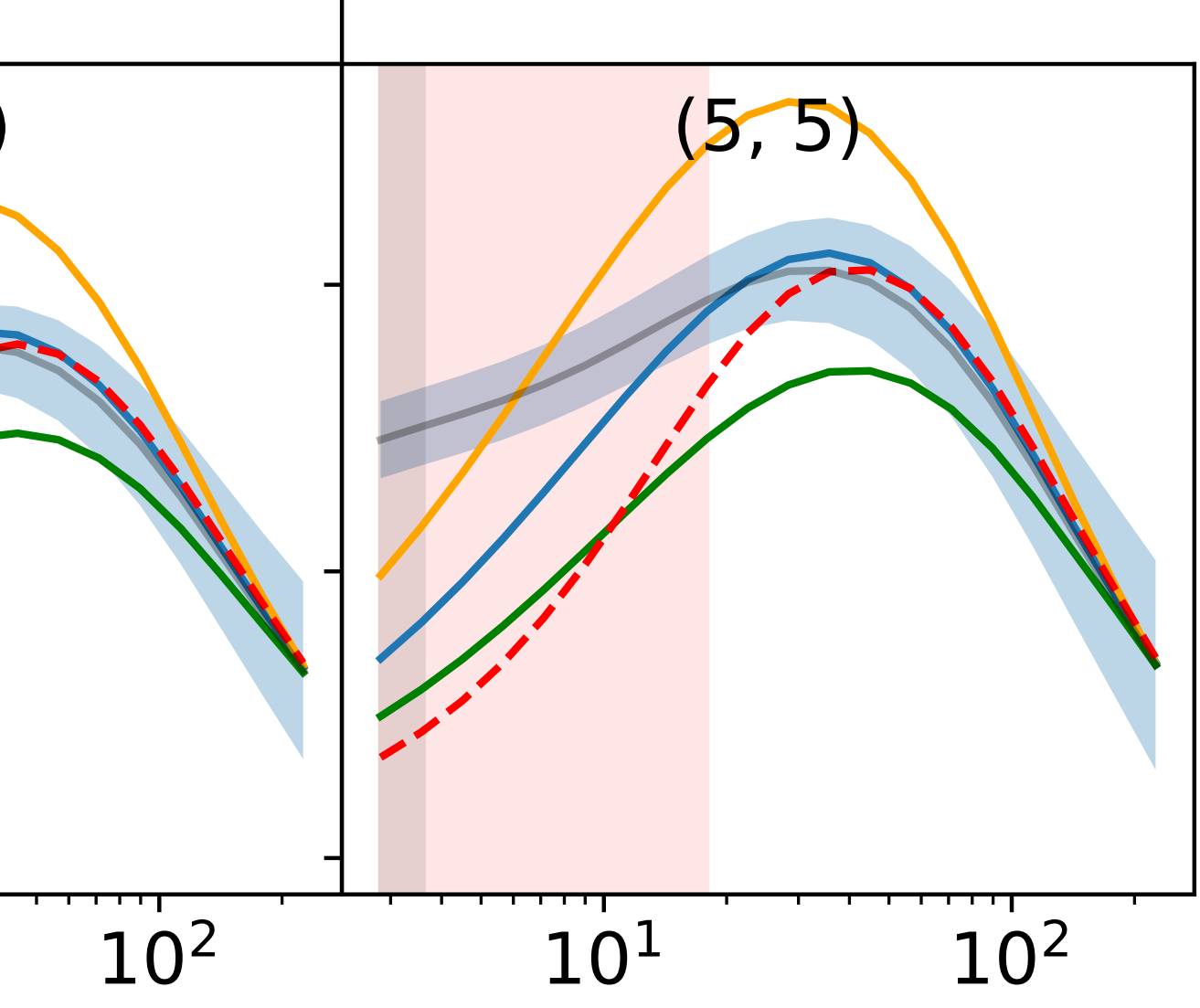
$$\gamma^{ij}_{\rm t}(\theta) = \int \frac{dl\, l}{2\pi} J_{2}(l\theta) C^{ij}_{\delta\kappa}(l)$$

$$w^{i}(\theta) = \sum_l \frac{2l+1}{4\pi} P_l\left(\cos(\theta)\right)\, C^{ii}_{\delta\delta}(l)$$

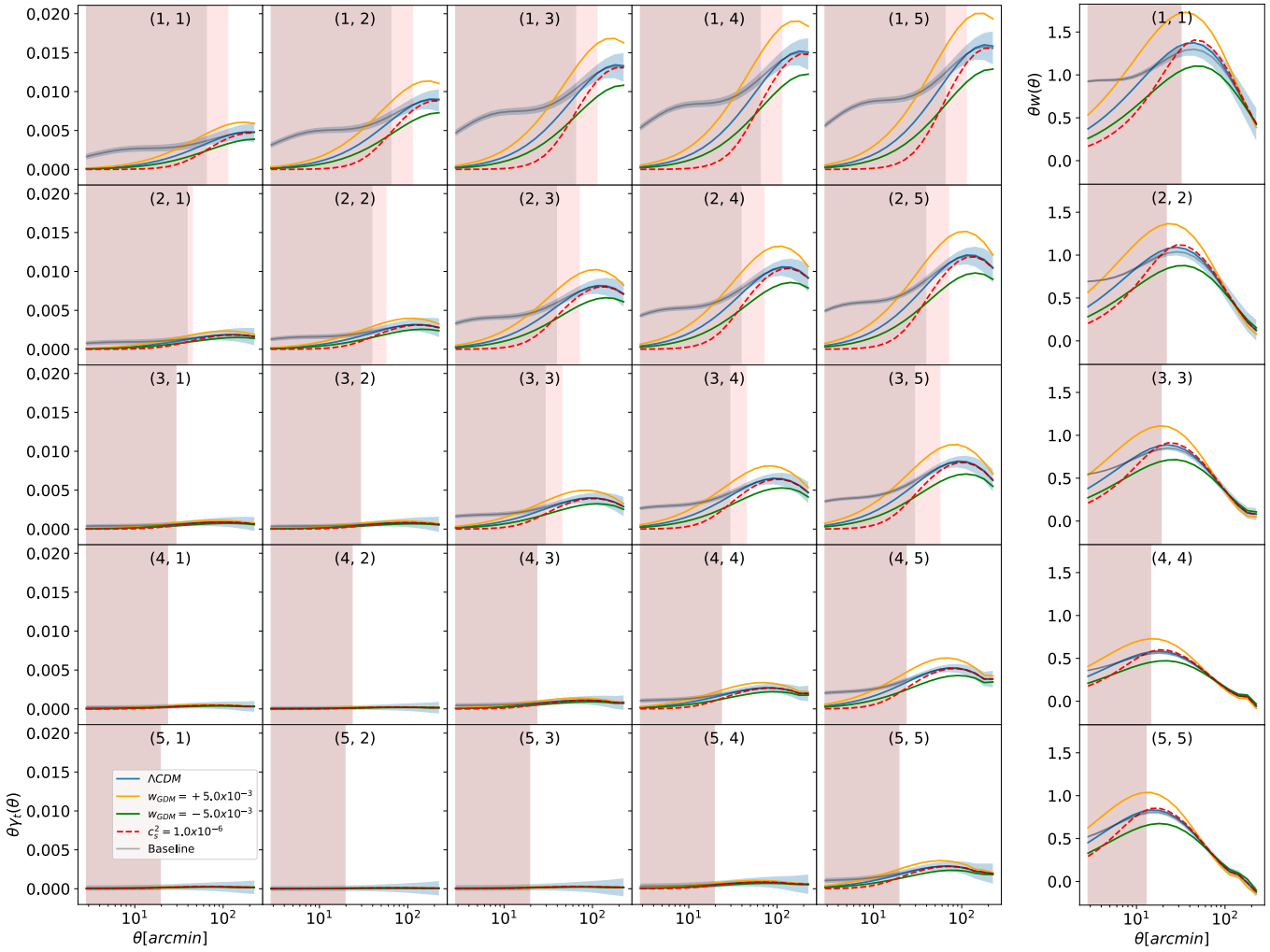
Krause et al., DES Y1 Results: Multi-Probe Methodology and Simulated Likelihood Analyses, 1706.09359.

3X2PT CORRELATION FUNCTIONS

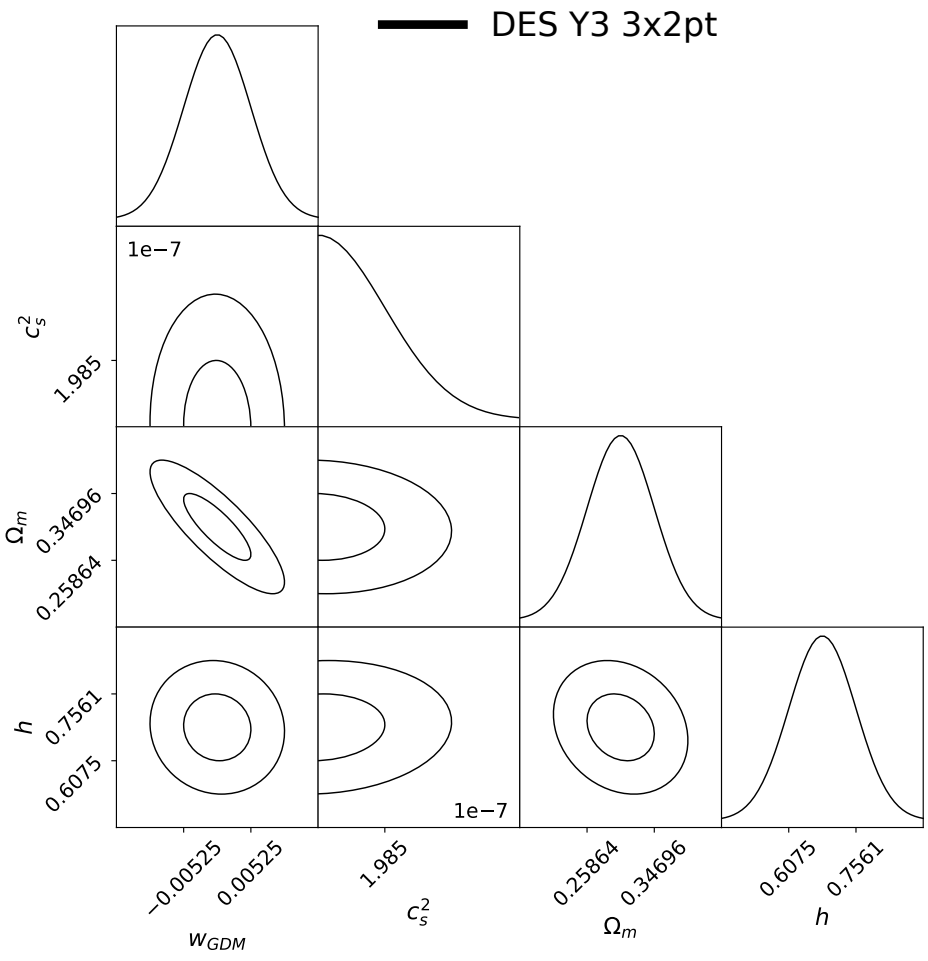



(5, 5)
10^2
10^1
10^2

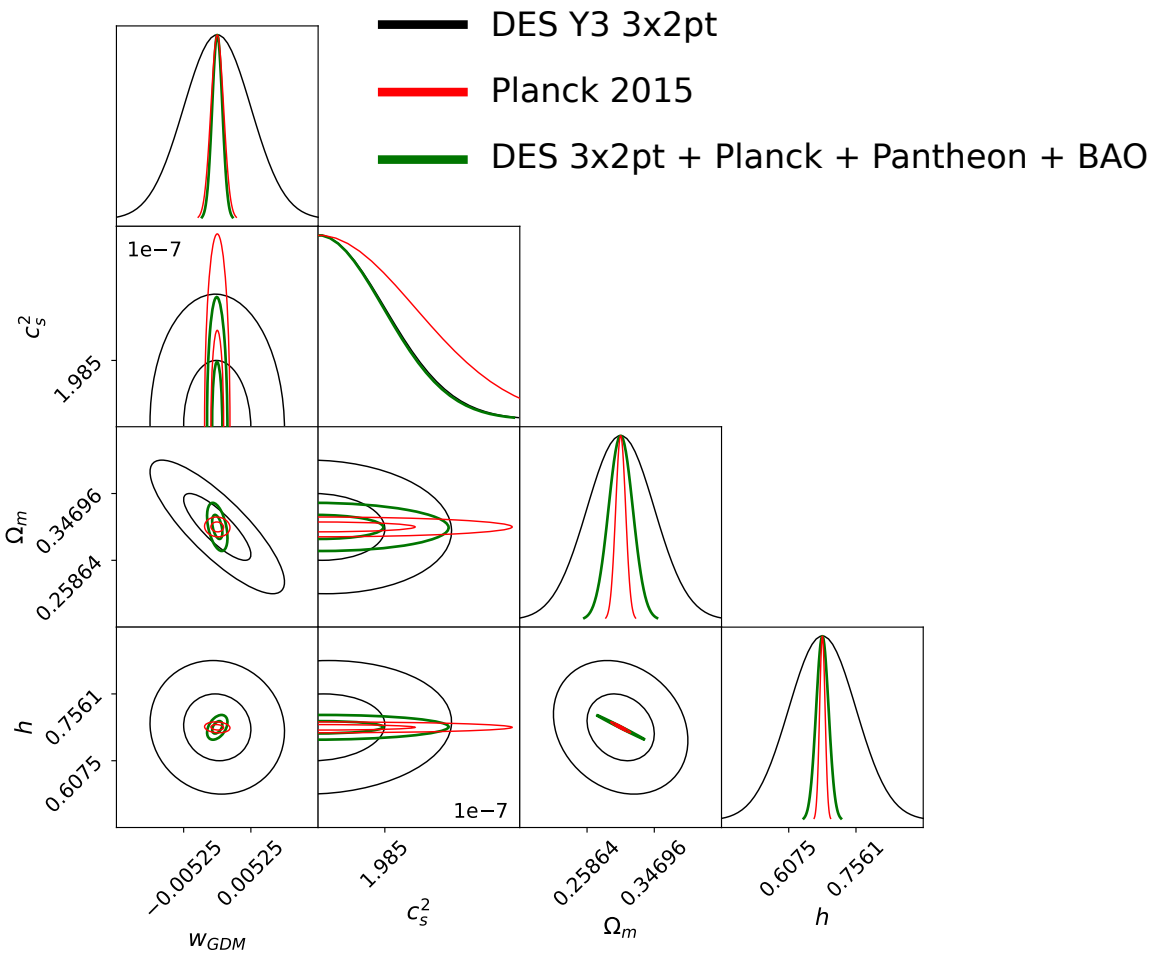
3X2PT CORRELATION FUNCTIONS



FISHER FORECAST



FISHER FORECAST



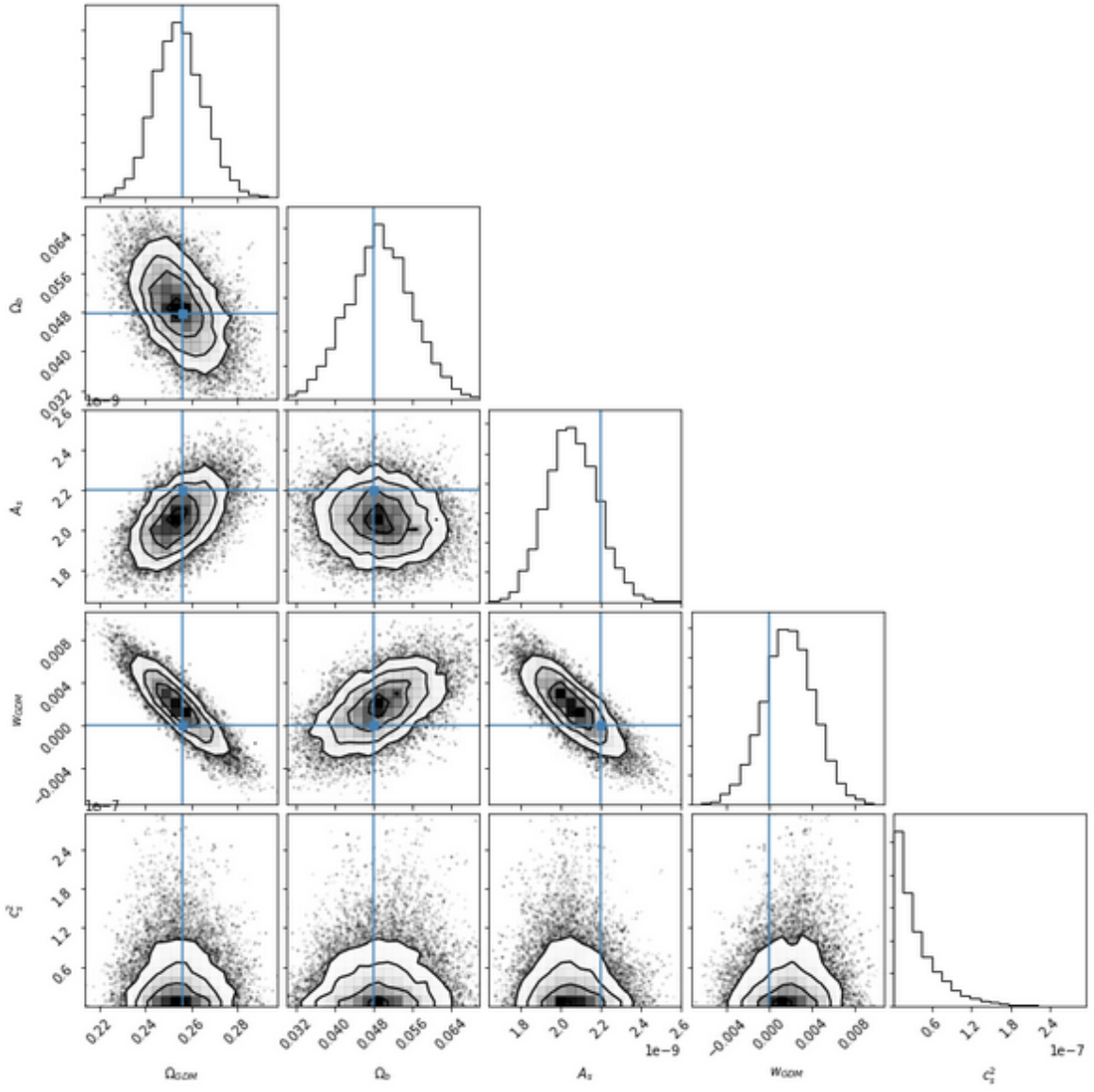
CHALLENGES

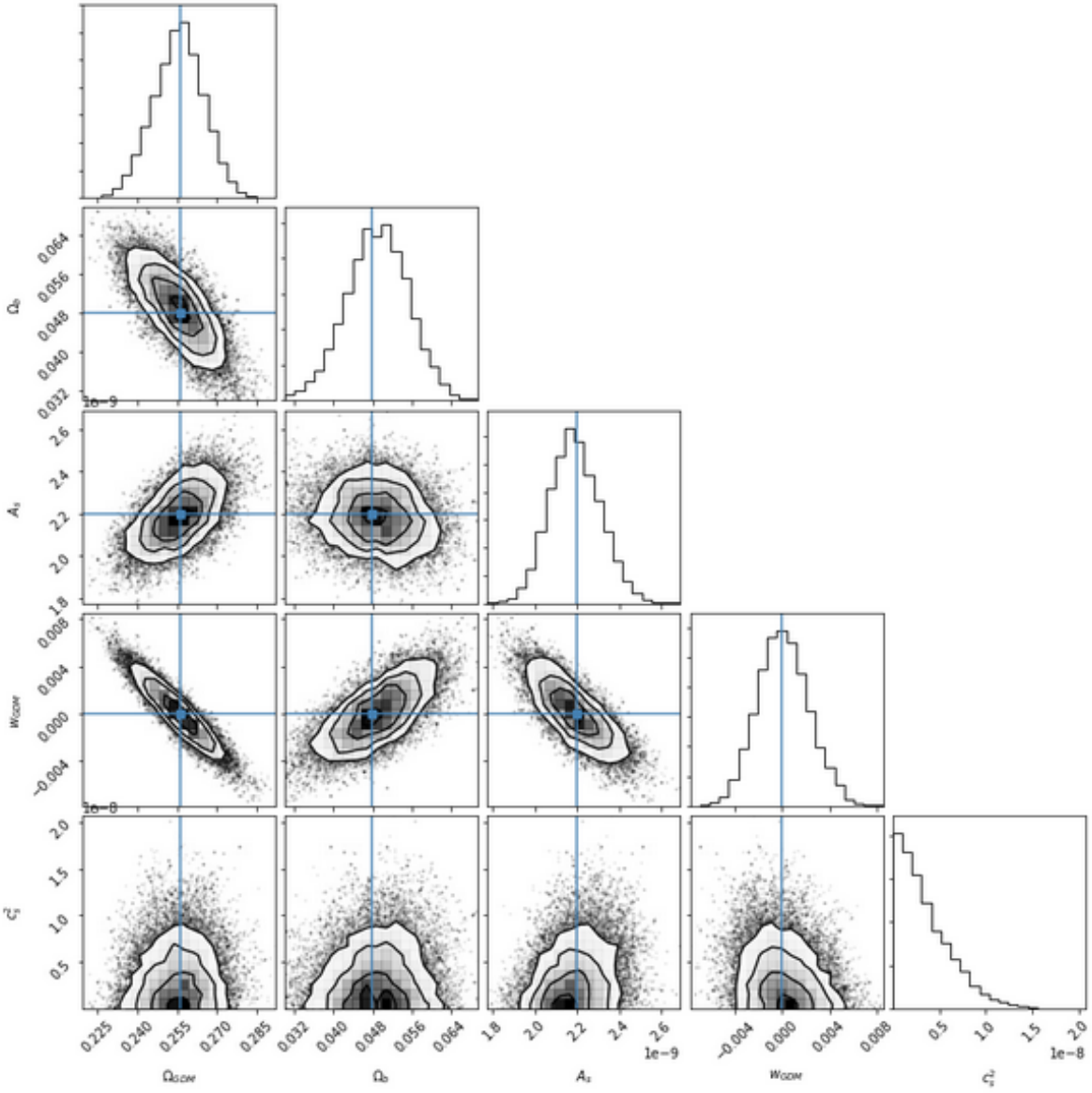
How to model non-linear scales?

CHALLENGES

How to model non-linear scales?

Don't. Exclude non-linear scales from the analysis.


Ω_{GDM}
Ω_b
A_s
w_{GDM}
c_s^2
1e−9
1e−7


Ω_{DDM}
Ω_b
A_s
w_{DDM}
c_s^2
1e−9
1e−8

CHALLENGES

How to model non-linear scales?

Don't. Exclude non-linear scales from the analysis.

Daniel B. Thomas, Michael Kopp, Katarina Markovič
Using LSS data and a halo model to constrain GDM (1905.02739)

“for k < 0.1h/Mpc, the agreement between our halo model and halofit is better than 2% and sufficient.”

CHALLENGES

How to model non-linear scales?

Don't. Exclude non-linear scales from the analysis.

Daniel B. Thomas, Michael Kopp, Katarina Markovič
Using LSS data and a halo model to constrain GDM (1905.02739)

“for k < 0.1h/Mpc, the agreement between our halo model and halofit is better than 2% and sufficient.”

What is the error introduced by using a fixed covariance matrix?

CHALLENGES

How to model non-linear scales?

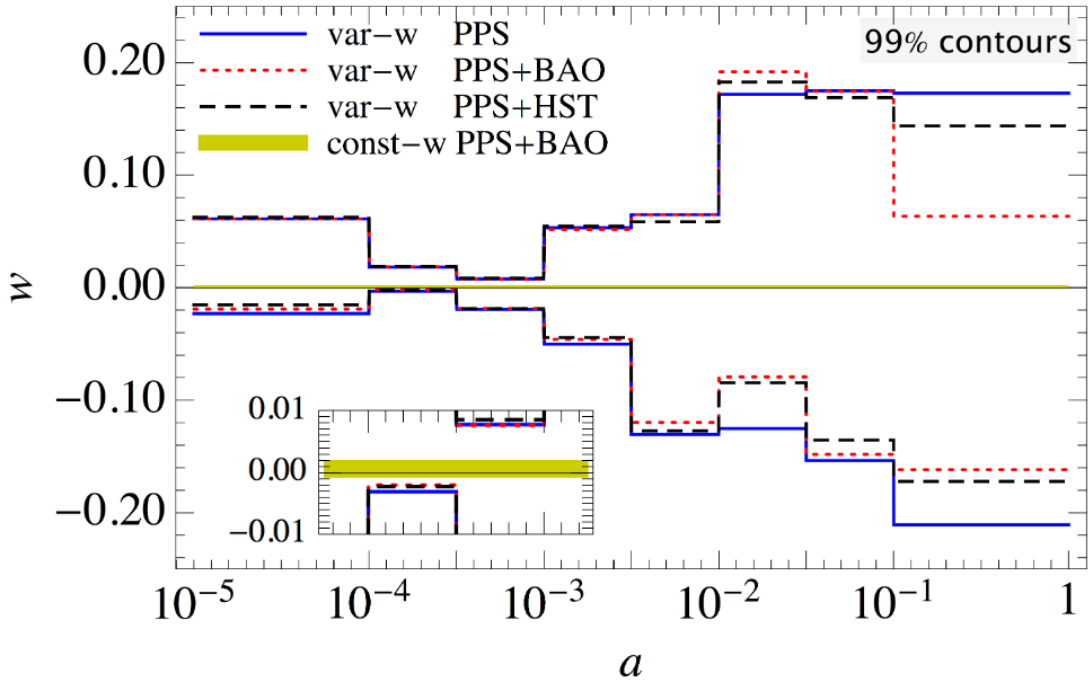
Don't. Exclude non-linear scales from the analysis.

Daniel B. Thomas, Michael Kopp, Katarina Markovič
Using LSS data and a halo model to constrain GDM (1905.02739)

"for k < 0.1h/Mpc, the agreement between our halo model and halofit is better than 2% and sufficient."

What is the error introduced by using a fixed covariance matrix?

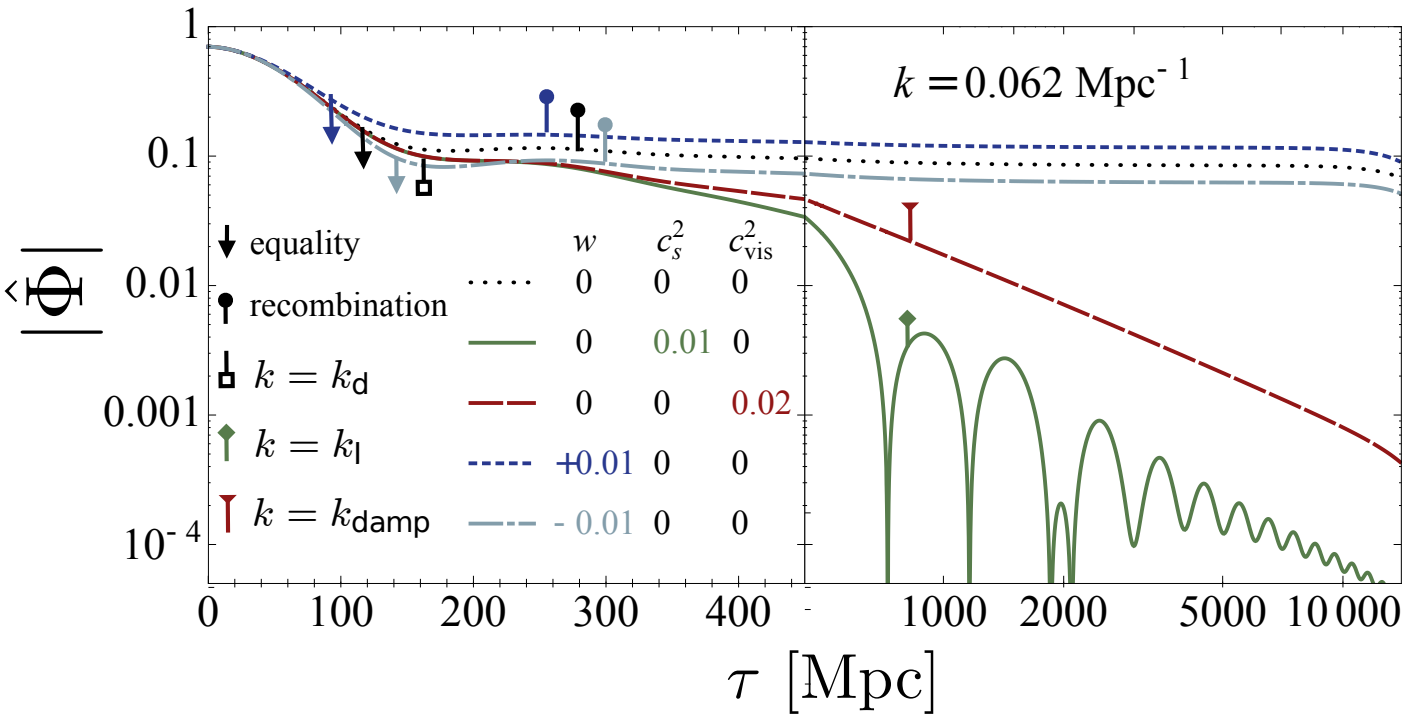
Could a detection of GDM be result of systematics?



Michael Kopp, Constantinos Skordis, Daniel B. Thomas, Stéphane Ilić
The Dark Matter equation of state through cosmic history (1802.09541)

THANK YOU!

GENERALIZED DARK MATTER



Kopp et al., 1605.00649

GENERALIZED DARK MATTER

$$T_{\mu\nu} = (\rho + p)u_\mu u_\nu + p g_{\mu\nu} + \Pi_{\mu\nu}$$

GENERALIZED DARK MATTER

$$T_{\mu\nu} = (\rho + p)u_\mu u_\nu + p g_{\mu\nu} + \Pi_{\mu\nu}$$

ρ	scalar (1)
p	scalar (1)
u_μ	scalar (1) + vector (2)
$\Pi_{\mu\nu}$	scalar (1) + vector (2) + tensor (2)

GENERALIZED DARK MATTER

$$T_{\mu\nu} = (\rho + p)u_\mu u_\nu + p g_{\mu\nu} + \Pi_{\mu\nu}$$

ρ	
p	scalar (1)
u_μ	
$\Pi_{\mu\nu}$	scalar (1) + vector (2) + tensor (2)

GENERALIZED DARK MATTER

$$T_{\mu\nu} = (\rho + p)u_\mu u_\nu + p g_{\mu\nu} + \Pi_{\mu\nu}$$

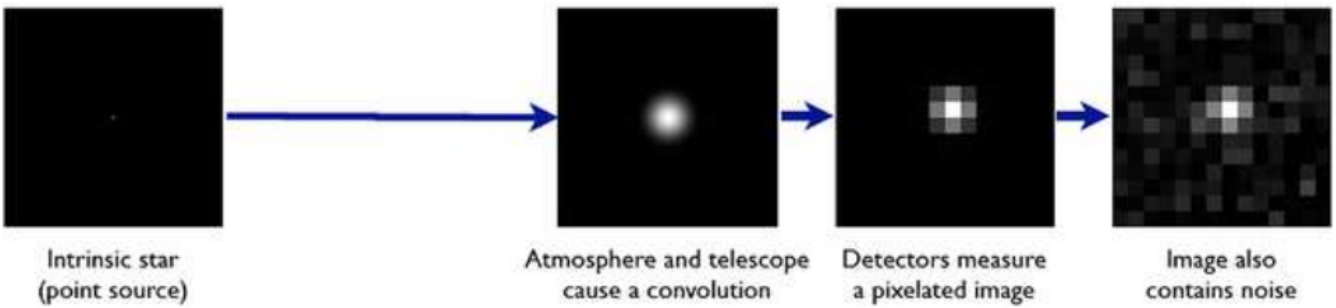
ρ	
p	scalar (1)
u_μ	
$\Pi_{\mu\nu}$	scalar (1)

THE DARK ENERGY SURVEY

The Forward Process.

Galaxies: Intrinsic galaxy shapes to measured image:

Stars: Point sources to star images:



Bridle et al. (0802.1214)

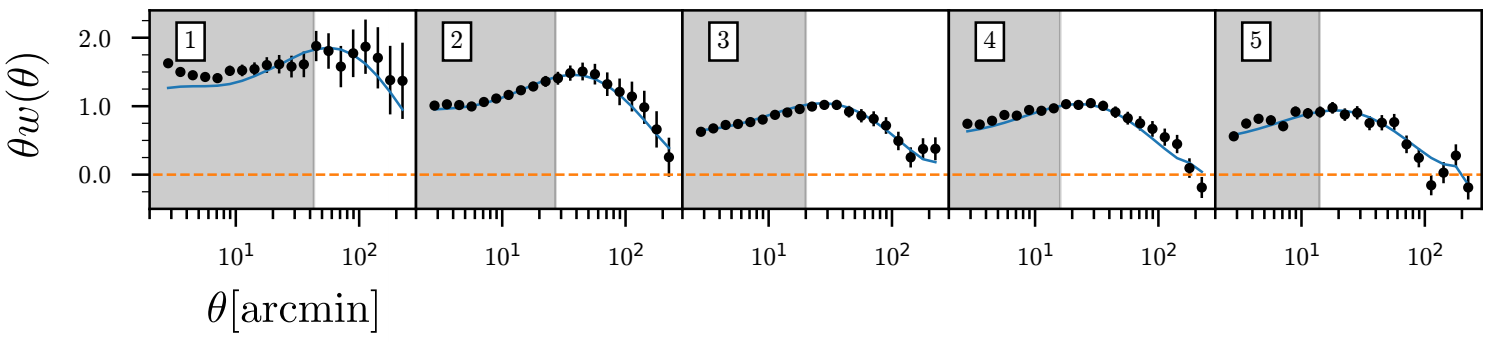
THE DARK ENERGY SURVEY

$$ds^2 = a(\eta)^2[-(1+2\Phi)d\eta^2 + (1-2\Phi)dx^2]$$

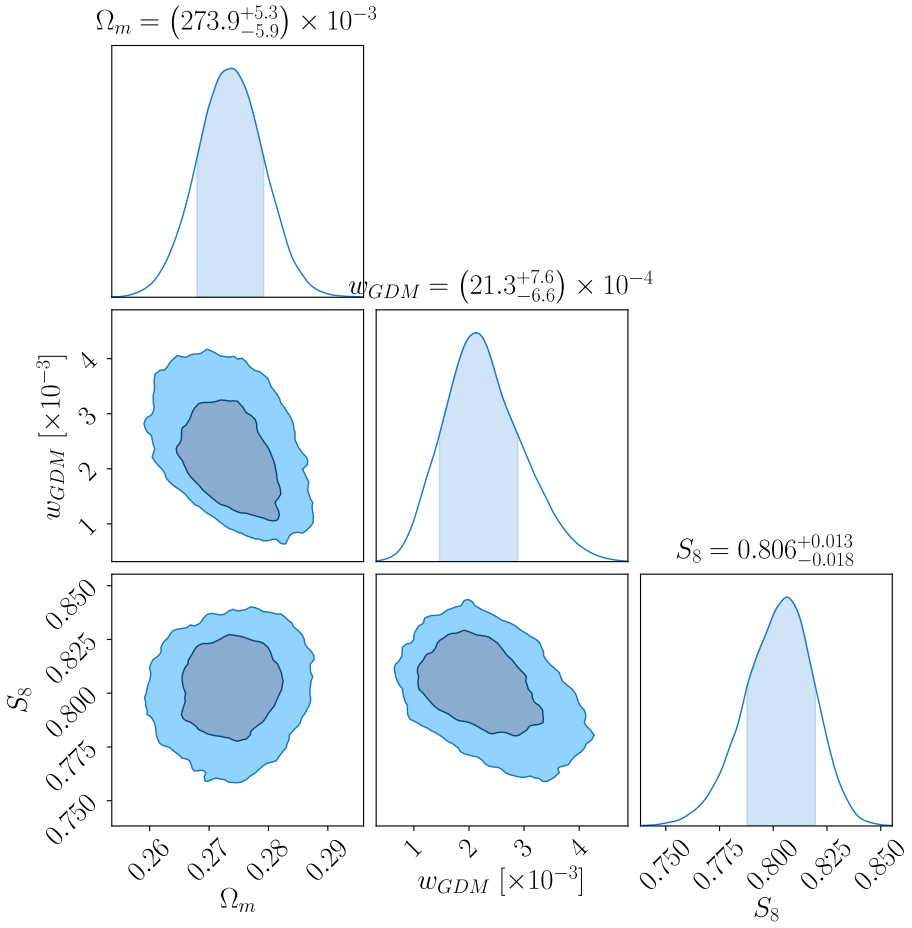
$$n = 1 - 2\Phi$$

$$\vec{\alpha} = \nabla_\theta[\frac{2D_{LS}}{D_L D_S}\int \Phi dz]$$

THE DARK ENERGY SURVEY



PARAMETER ESTIMATION



PARAMETER ESTIMATION