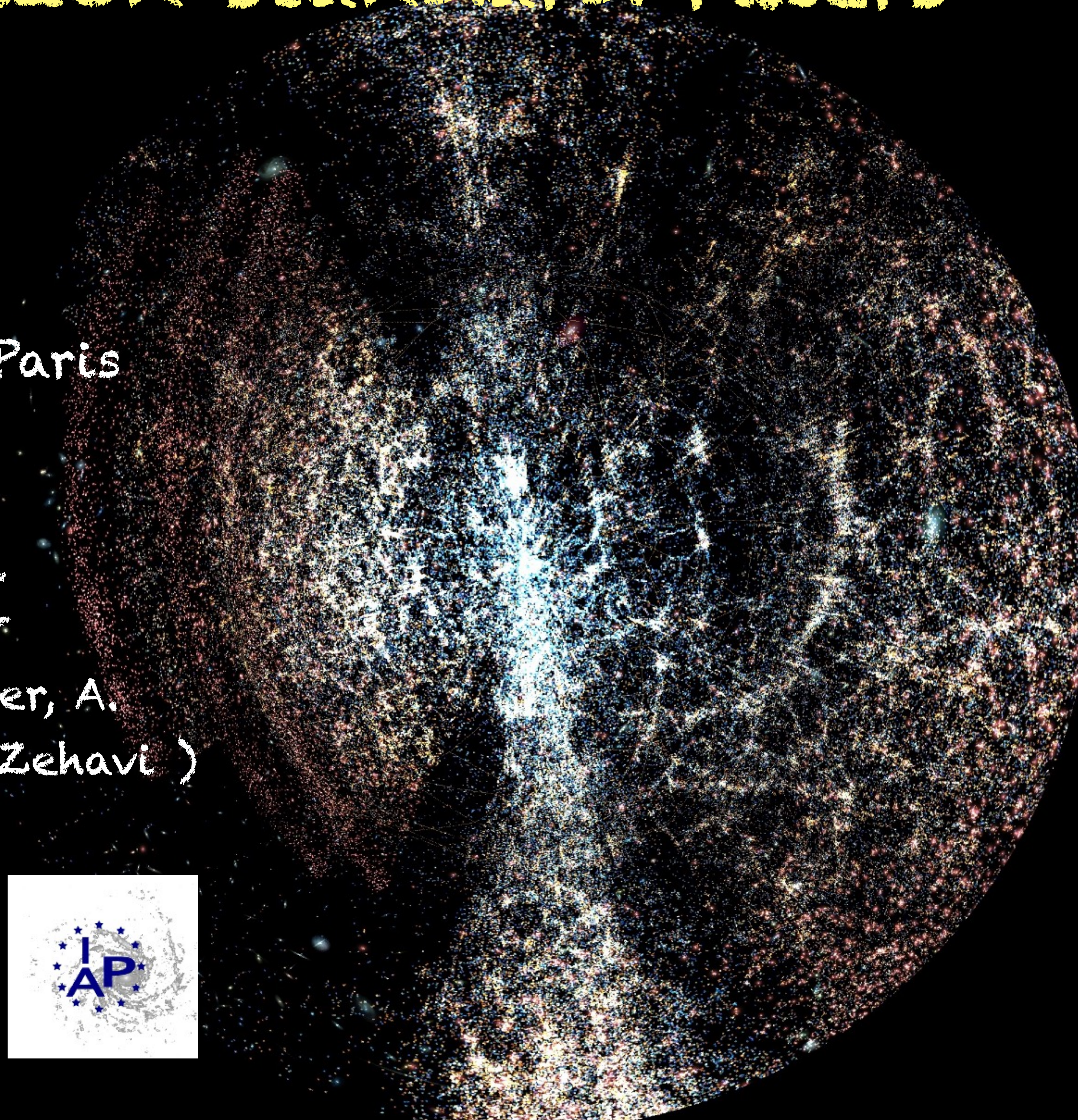
Cosmological synergies with “Purely Geometric BAO” methods: Linear Point and Sound Horizon standard rulers



CoSyne - IAP 2019

Institut d’Astrophysique de Paris

December 10, 2019

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Outline

GOAL

- Constrain cosmological models.
  Combining different Cosmological observations.
- Consistency checks of cosmological models.

From Baryon Acoustic Oscillations?

Purely-Geometric-BAO

- Model independent: LINEAR POINT standard ruler
- Model dependent: SOUND HORIZON standard ruler

Baryon Acoustic Oscillations

- IDEA: Preferred scale at early and late times

Early: sound horizon r_d ⟷ Late: 2pcf peak position s_p

model-indep. cosmological distances

- Non-linearities

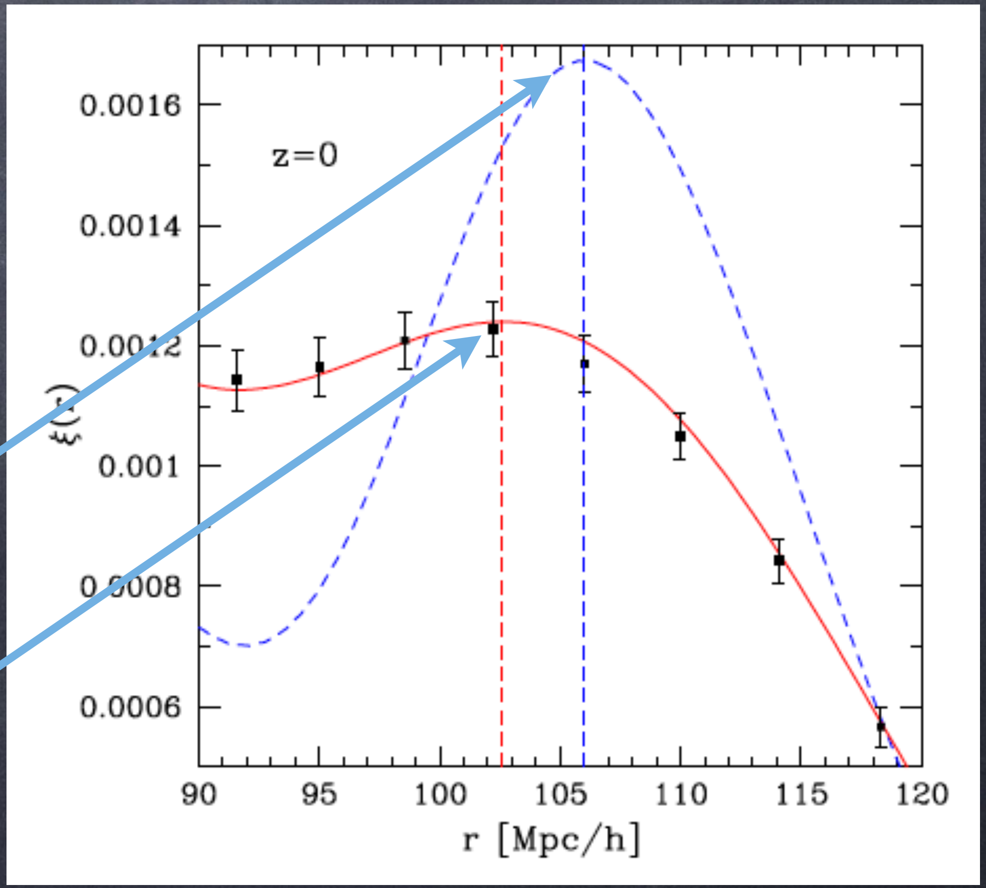
non-linear gravity, RSD, scale-sep bias

- peak distorted and shifted

- Different treatment needed!!

linear

non-linear



Smith et al (2008) *Crocce, Scoccimarro (2008)*

What from BAO?

S.A, Corasaniti, Sanchez, Starkman, Sheth, Zehavi - PRD (2019)

Cosmological distances that are estimated under the following theoretical conditions:

1) Geometrical (indep. primordial fluctuation parameters)

2) Dark-Energy model-independent (ΛCDM + Quintessence)

3) Spatial curvature-independent

4) Tracer-independent (galaxy, quasars, clusters etc...)

Purely-Geometric-BAO

Cosmological Distance: Dv

isotropic volume distance

$$D_V(z) = \left[(1+z)^2 D_A^2(z)\frac{cz}{H(z)}\right]^{1/3}$$

- Alcock-Paczynski: 2pcf-monopole equation

Distorted True small correction

FROM $\xi_0^D(s^F) = \xi_0^T(\alpha s^F) + O(\epsilon)$

Isotropic shift

$\alpha = D_V(z)/D_V^F(z)$

MEASURED CONSISTENTLY with the PG-BAO conditions

2 options

- Alcock-Paczynski equation

$$\xi_0^D(s^F) = \xi_0^{\text{model}}\left(\alpha\, s^F\right) + O(\epsilon)$$

DATA THEORY

$$L_{\text{st. ruler}}/D_V(z)$$

LINEAR POINT

- 0.5% indep. non-linearities
- Linear theory
- 2pcf MODEL INDEPENDENT

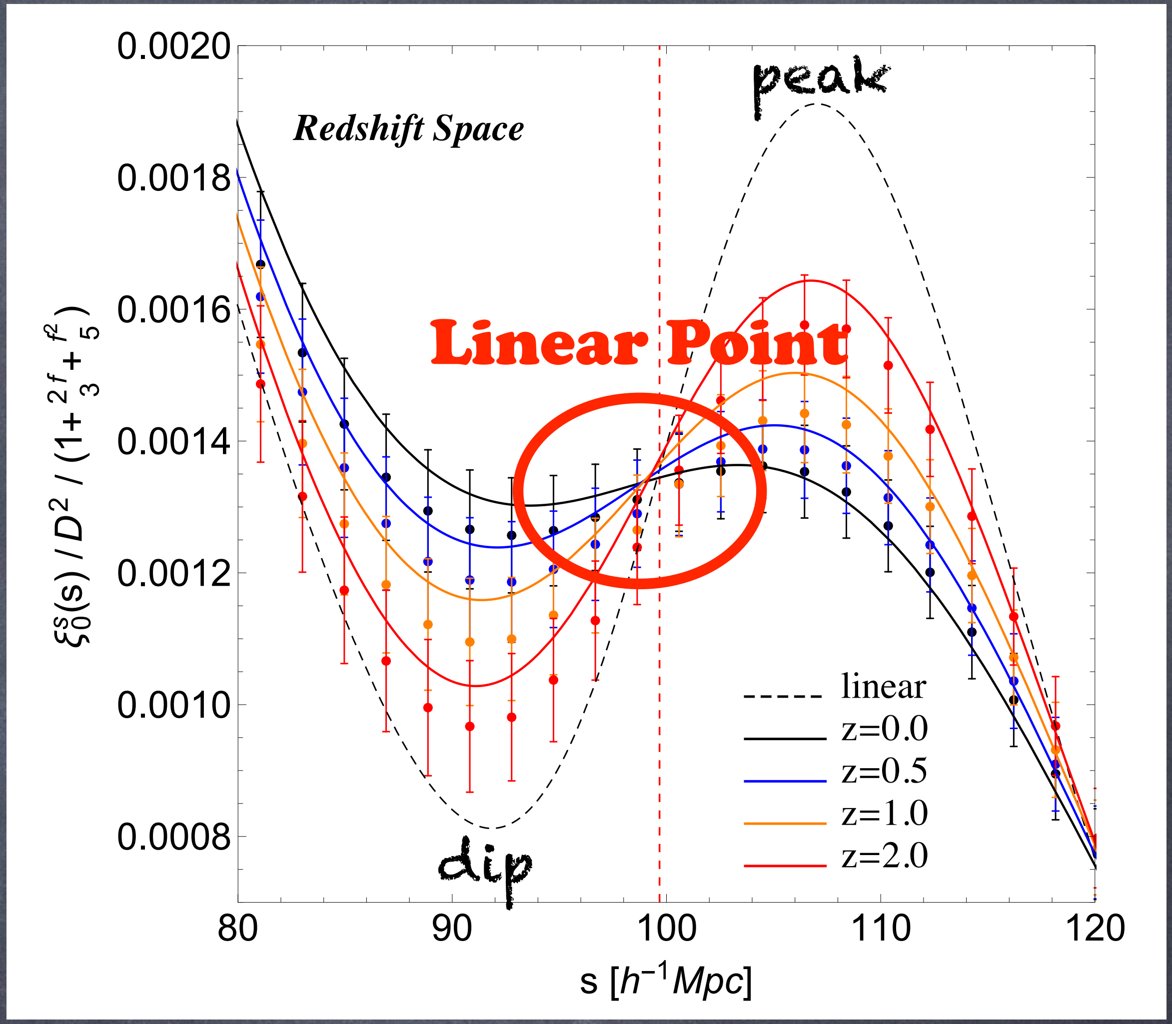
SOUND HORIZON

- Model non-linearities
- Secondary parameter
- 2pcf MODEL DEPENDENT

New Standard Ruler: the Linear Point

S.A, Starkman, Sheth - MNRAS (2016)

Only assumption:
cosmological model(s)



- LINEAR POINT
  - LP = peak-dip middle point
  - Linear at 0.5% -> red. indep.
- NO 2pcf MODEL NEEDED

DATA

LINEAR THEORY

$$\xi_0^D\left(y_{LP}^{\rm gal}(z)\right) = \xi_0^{\rm lin}\left(\frac{s_{LP}(\omega_b,\omega_c)}{D_V^T(z)}\right) + O(\epsilon)$$

model-independent parametric fit

CAMB code

Sound Horizon: 2pcf model-fitting

S.A, Corasaniti, Sanchez, Starkman, Sheth, Zehavi - PRD (2019)

- Purely-Geometric-Distances

DATA — NON-LIN. THEORY

$$\xi_0^D(s^F) = \xi_0^{\text{model}}\left(\alpha\, s^F\right) + O(\epsilon)$$

- Assume a non-linear 2pcf template
- Fit $\theta_\mu = \{\omega_b, \omega_c, n_s, D_V(z), \ldots\}$

Marginalize over:
- DE, curvature dep. param.
- non-lin, astroph. param.
- 2pcf template dependent

constrain

$$\frac{r_d(\omega_b, \omega_c)}{D_V(z)}$$

Problem: which template? -> error estimation?

Standard BAO

Seo et al. (2008)
Xu et al. (2012)

- 2pcf template + fitting prescription

$$\xi_0^D(s^F) = B^2 \xi_m^{\text{fixed}}\left(\alpha\, s^F\right) + \xi^{\text{BB}}(s^F) + O(\epsilon)$$

min. model
(non-lin. damping)

$$\xi^{\text{BB}}(s^F) = \frac{a_1}{(s^F)^2} + \frac{a_2}{s^F} + a_3$$

FIXED parameters

$$\theta_\mu^{\text{fixed}} = \{\omega_b^F, \omega_c^F, n_s^F, \sigma_0^F\}$$

5 varied parameters

$$\theta_\mu = \{\alpha, B, a_1, a_2, a_3\}$$

marginalized

Cosmological information

- Because of cosm. param. fixing

$$\alpha = \frac{D_V(z)}{D_V^F(z)} \frac{r_d^F}{r_d}$$

prescription

fitting prescription does not guarantee proper error propagation

Linear Point and 2pcf-model

S.A, Corasaniti, Sanchez, Starkman, Sheth, Zehavi - PRD (2019)

- Example with minimal BAO model (non-lin. damping)

- Theoretical investig.

Linear Point → LP

2pcf-model → CF-MF

DESI + Euclid forecasts

	LP	CF-MF
$\bar{z}$	$\frac{s_{LP}}{D_V(\bar{z})}$	$\frac{r_d}{D_V(\bar{z})}$
0.15	**2.9%**	**6.1%**
0.4	**2.3%**	**4.3%**
0.7	**1.2%**	**1.8%**
0.9	**0.9%**	**1.3%**
1.1	**0.7%**	**1.1%**
1.3	**0.7%**	**1.0%**
1.5	**0.8%**	**1.0%**
1.7	**1.1%**	**1.3%**
1.9	**2.0%**	**2.3%**

- Linear Point
  - no-2pcf-model assumptions
  - more precise distances

- For full comparison: s_{LP} and r_d characterization needed

from PG-BAO to Cosmology

O'Dwyer, S.A, Starkman, Corasaniti, Sheth, Zehavi - arXiv: 1910.10698

- Possible/common Purely-Geometric-BAO usage:
  - Model selection of cosmological models
  - Detection of late-time acceleration
  - Model/data consistency checks

- To use PG-BAO for cosmology: characterization needed

from BAO

$s_{LP}(\omega_b, \omega_c)/D_V(z)$

$r_d(\omega_b, \omega_c)/D_V(z)$

rulers

param. dependence →

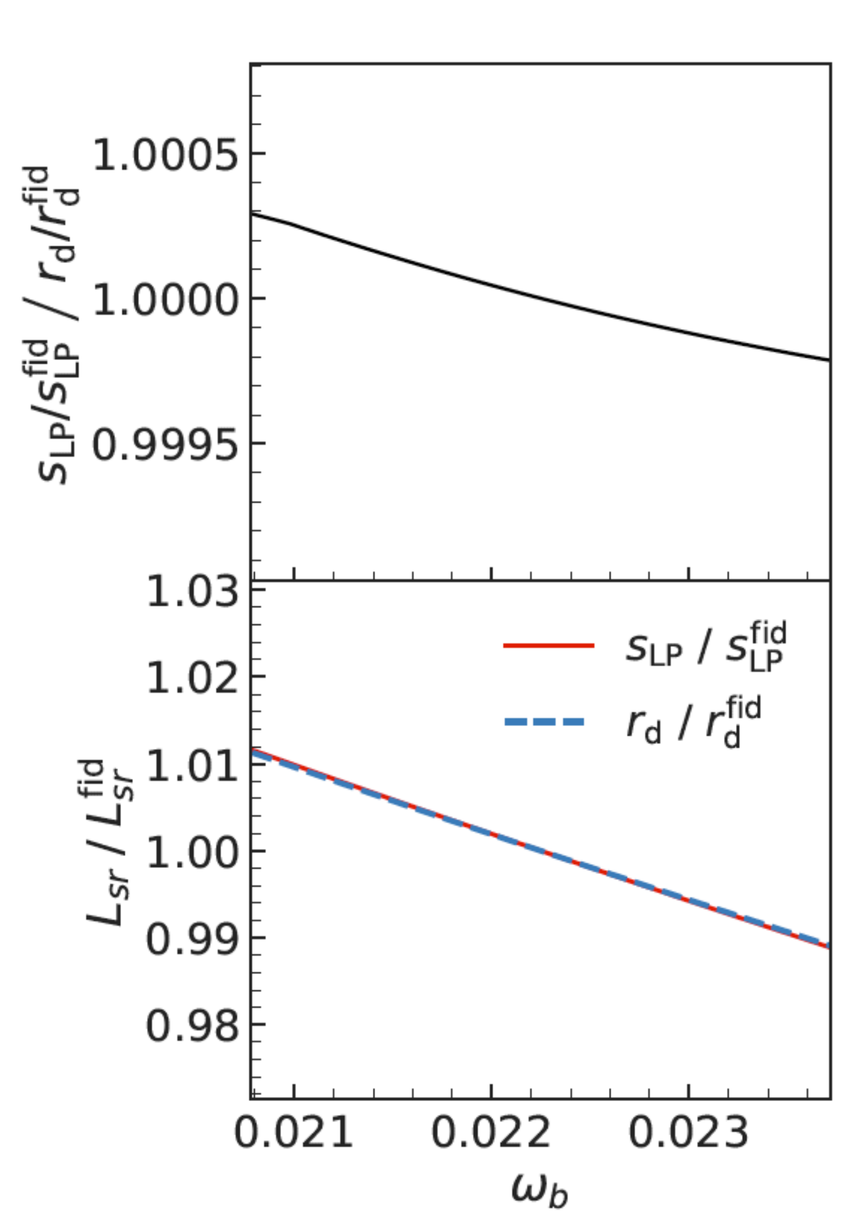
COSMOLOGY

ruler characterization

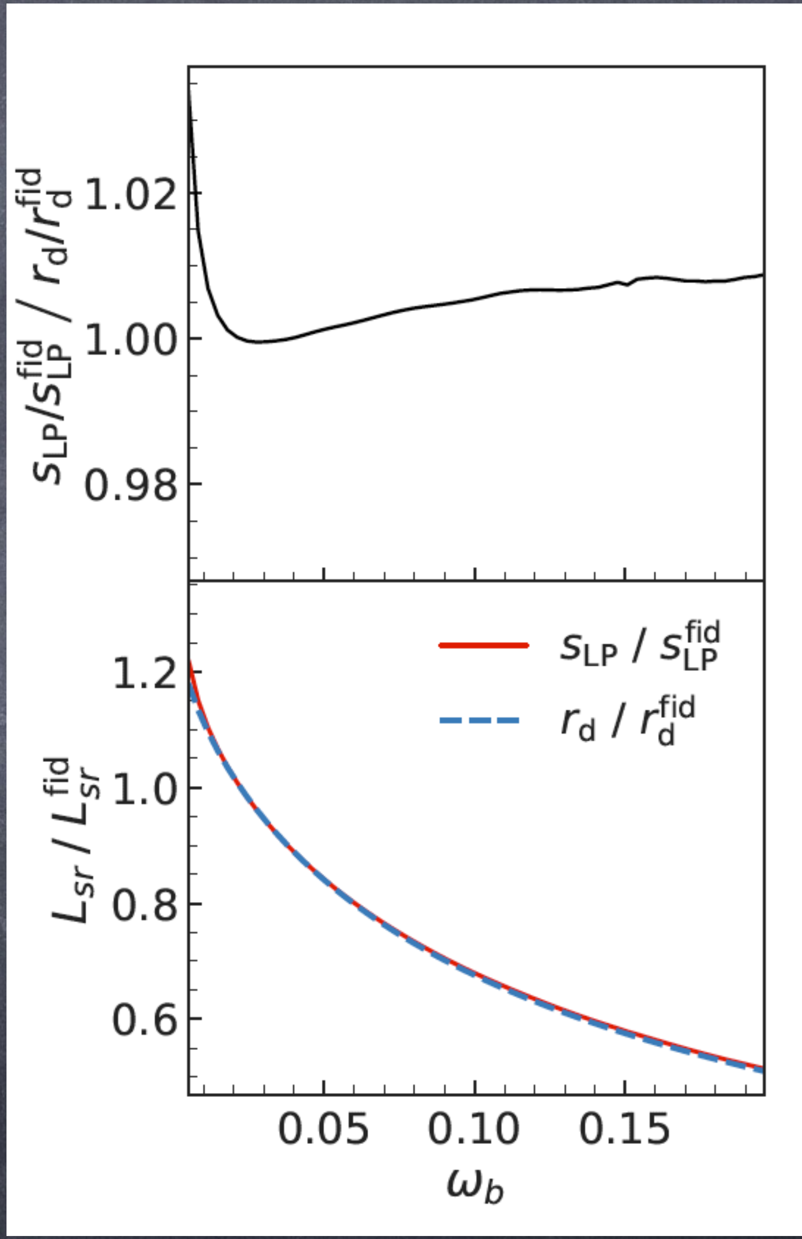
O'Dwyer, S.A, Starkman, Corasaniti, Sheth, Zehavi - arXiv: 1910.10698

- BAO need to go beyond 10σ Planck
- 10σ Planck: same par. dep.
- Wider range: small difference -> no problem
- Problem: non-lin. physics for wider param. range

Within 10σ Planck



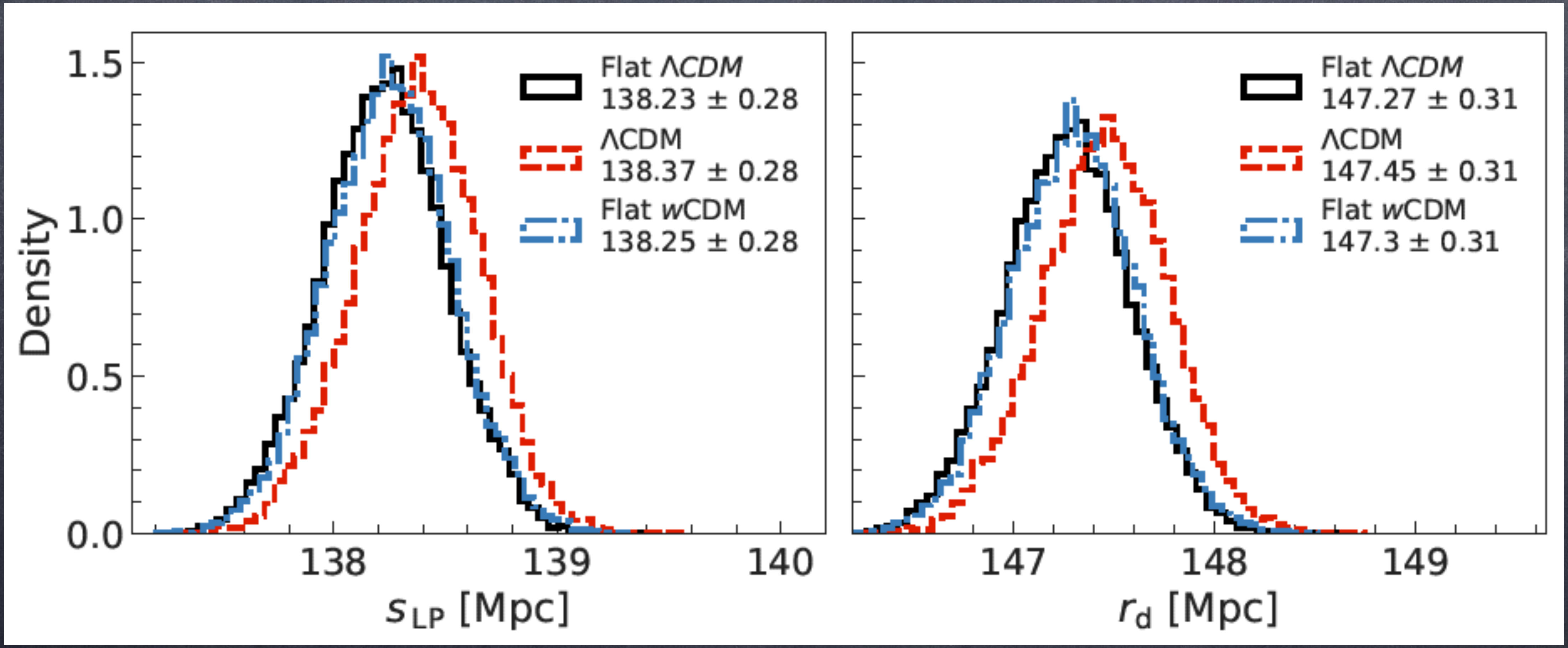
Wider param. range



rulers from CMB

O'Dwyer, S.A, Starkman, Corasaniti, Sheth, Zehavi - arXiv: 1910.10698

- Purely-Geometric-BAO: only late-time information but...
- From Planck posterior to s_{LP} and r_d
- Models: flat-ΛCDM, kΛCDM and flat-wCDM



- Same errors
- Late Universe physics shifts the rulers?

Final Remarks

- Purely-Geometric BAO crucial for Cosm. Synergies
- Cosmic Distance Measurements

  Independent of cosmological background model

Operatively →

Linear Point Standard Ruler

No assumptions beyond cosm. models

Biased at 0.5%

Operatively →

Sound Horizon - 2pcf Model-Fitting

Which 2pcf-model? Range of scales?

Distance errors?

- s_{LP} and r_d: basically the same parameter depend.
- s_{LP} and r_d from CMB: can have a model-dep. shift
- Problem: non-linearities for wide parameters' ranges.