

Model-independent curvature test and H_0 measurement

L'Huillier & Shafieloo JCAP subm., arXiv:1606.06832

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Outline

- 1 A model-independent reconstruction of the expansion history: curvature test and H_0 measurement
- 2 DM Haloes in MoG
- 3 Constraining the early Universe with the LSS

Testing the metric and flatness

L'Huillier & Shafieloo (2016) 1606.06832, JCAP subm.

Concordance model: Isotropic and homogeneous $\rightarrow$

Friedmann-Lemaître-Robertson-Walker (FLRW) metric

Need to test the metric (c.f. Arman's talk)

Metric test: the $\mathcal{O}_k$ parameter (Clarkson et al. 2008)

$$\mathcal{O}_k(z) = \frac{\left(\frac{H(z)\mathcal{D}'(z)}{H_0} \right)^2 - 1}{\mathcal{D}^2(z)} \quad (1)$$

- $\mathcal{O}_k(z) = \text{Cst}$ for FLRW Universe (0 for flat)
- Need $H(z)$, H_0 , $\mathcal{D}(z)$, and $\mathcal{D}'(z)$
- $H(z)$ from BAO
- $\mathcal{D}, \mathcal{D}'(z)$ from supernovae

Iterative smoothing (Shafieloo et al. 2006, Shafieloo 2007)

- Distance modulus $\mu(z_i)$
- Non-parametric, model-independent method
- Iterative smoothing with log-normal kernel
- Start with initial (parametric) guess (for instance best-fit flat- Λ CDM, SCDM, EdS, w CDM, ...): $\hat{\mu}_0(z)$

$$\hat{\mu}_{n+1}(z) = \hat{\mu}_n(z) + N(z) \sum_i \left(\frac{\mu(z_i) - \hat{\mu}_n(z_i)}{\sigma_i^2} \exp \left(-\frac{\ln^2 \left(\frac{1+z_i}{1+z} \right)}{2\Delta^2} \right) \right), \quad (2)$$

- Keep all reconstructions with $\chi^2 < \chi_{\text{flat } \Lambda\text{CDM}}^2$

where $N^{-1}(z) = \sum_i \left(1/\sigma_i^2 \exp \left(-\ln^2 \left((1+z_i)/(1+z) \right) / 2\Delta^2 \right) \right)$, is a normalisation factor, and

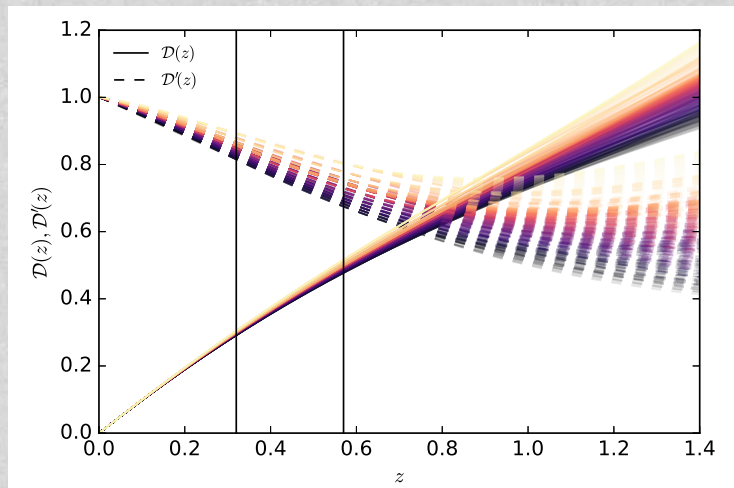
z_i : input redshift

z : desired output redshift

$\Delta = 0.3$: smoothing scale

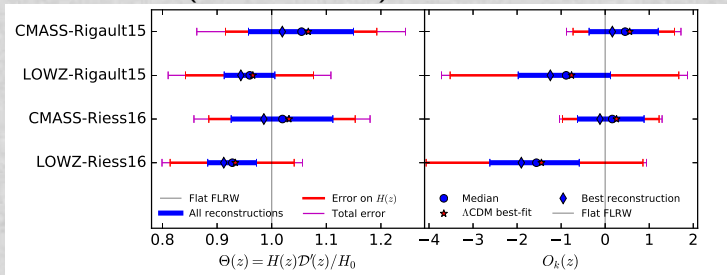
We obtain $\frac{H_0}{c} d_L(z) = (1+z)\mathcal{D}(z)$
 $\mathcal{D}'(z)$: Numerical derivation

Distance reconstruction



All lines have a better χ^2 to the JLA $\mu(z_i)$ than the best-fit flat- Λ CDM model

Metric test (1606.06832)

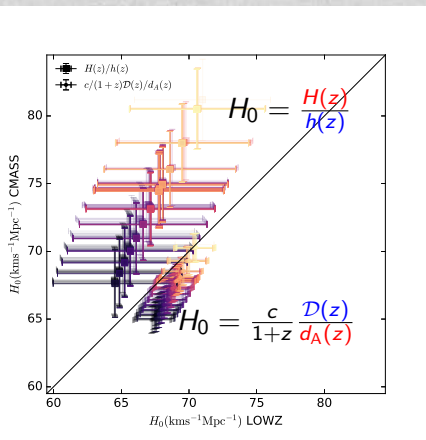


$$\mathcal{O}_k(z) = \frac{\left(\frac{H(z)D'(z)}{H_0}\right)^2 - 1}{D^2(z)} \quad (3)$$

- $H(z)$ from BAO (Cuesta et al 2016)
- $D(z), D'(z)$ from JLA supernovae (Betoule et al. 2014)
- Two different (local) H_0 : Rigault et al (2015), Riess et al. (2016)
- **Consistent with flatness**

Model-independent measurement of H_0

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- $H(z), d_A(z)$ from BAO (BOSS, Cuesta et al 2016)
- $h(z) = 1/\mathcal{D}'(z), \mathcal{D}(z)$:
model-independently
reconstructed from supernovae (JLA, Betoule et al 2014)
- $H_0 r_d = (10\,077.64 \pm 347.41) \text{ km s}^{-1}$
- Assuming $r_d = 147.1 \text{ Mpc}$, we find $H_0 = (68.51 \pm 2.36) \text{ km s}^{-1} \text{ Mpc}^{-1}$.

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DM Haloes in MoG

L'Huillier et al. in prep

With D. Mota (UiO), H. Winther (Oxford), C. Park & J. Kim (KIAS)

Studying DM Haloes in MoG

- GR or modified gravity (MoG)?
- Galaxy formation: interactions shape galaxies
- Alignment: source of systematics for weak lensing
- Follow up on studies in Λ CDM (L'Huillier, Park & Kim 2015, 2016 subm.)

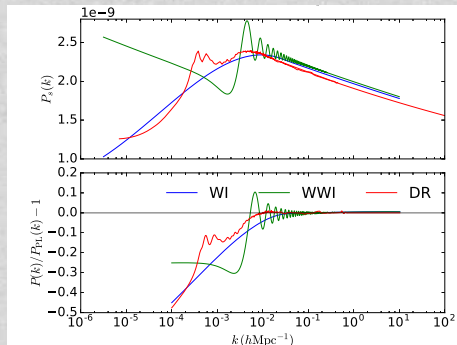
Simulations

- $f(R)$ (10^{-4} , 10^{-5} , 10^{-6}): $256 h^{-1}\text{Mpc}$, 512^3 , $1 h^{-1}\text{Gpc}$, 1024^3
- DGP ($r = 1.2$): $250 h^{-1}\text{Mpc}$, 512^3
- Dynamical DE Baldi et al 2012: $1 h^{-1}\text{Gpc}$, 1024^3

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Constraining the early Universe with the LSS



- 3 models (Whipped Inflation, Wiggly Whipped Inflation, Direct reconstruction)
- Can we use LSS to distinguish?
- N -body simulation:
1.89 $h^{-1}\text{Gpc}$, 1024^3 particles
- In progress... stay tuned!

Summary

- Model-independent reconstitution of the expansion
 - ▶ k -test: consistent with flat- FLRW
 - ▶ Model-independent measurement of H_0 from high- z
 - ▶ Need a model-independent estimation of r_d
- Haloes in MoG
 - ▶ Structural parameters and alignment: maybe hints of differences
 - ▶ Interaction rate: hard to distinguish
 - ▶ Need better statistics... larger simulations
 - ▶ Comparison to observations?
- Constraining the early Universe
 - ▶ In progress...

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谢谢!

감사합니다!

ありがとうございました!