Using cluster and weak lensing data to constrain $f(R)$ modified gravity models

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Future Cosmology IESC Cargesè

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Clustering in $f(R)$ Modified Gravity

We use Hu&Sawicki model

$$S = \int \mathrm{d}^4x \sqrt{-g} \left[\frac{R}{16\pi G} + \mathcal{L}\right] \longrightarrow S = \int \mathrm{d}^4x \sqrt{-g} \left[\frac{R + f(R)}{16\pi G} + \mathcal{L}\right]$$

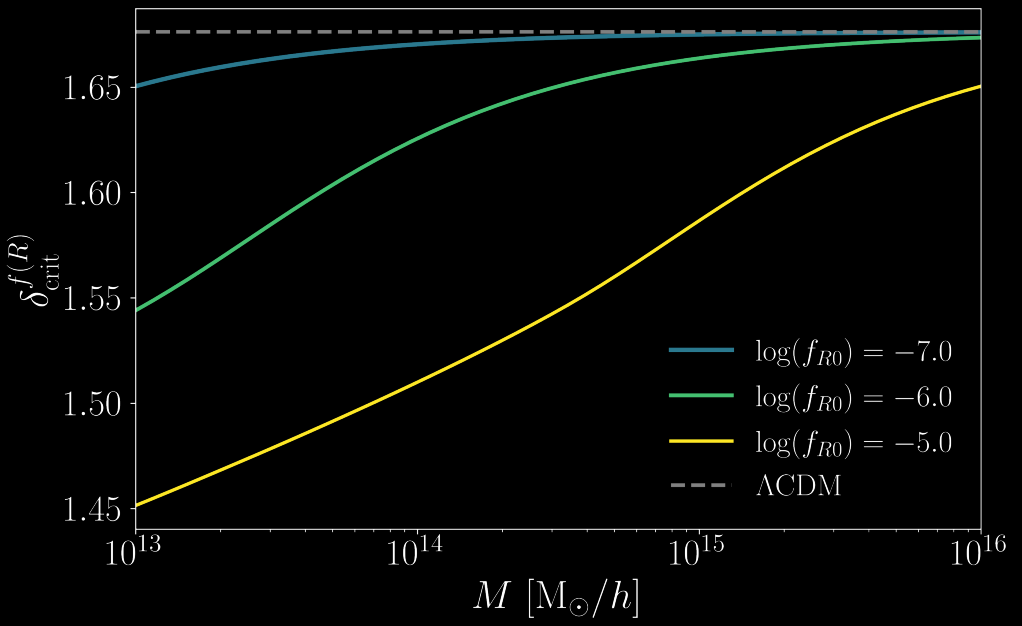
$$\nabla^2 \Phi = \frac{16\pi G}{3} \delta\rho \longrightarrow \nabla^2 \Phi = \frac{16\pi G}{3} \delta\rho - \frac{1}{6} \delta R$$

- Non-linear function $f(R)$ leads to scale-dependent structure growth
- Affects the distribution of galaxy clusters
- Cluster (like SZ surveys) and weak lensing (WL) surveys can constrain $f(R)$-gravity models

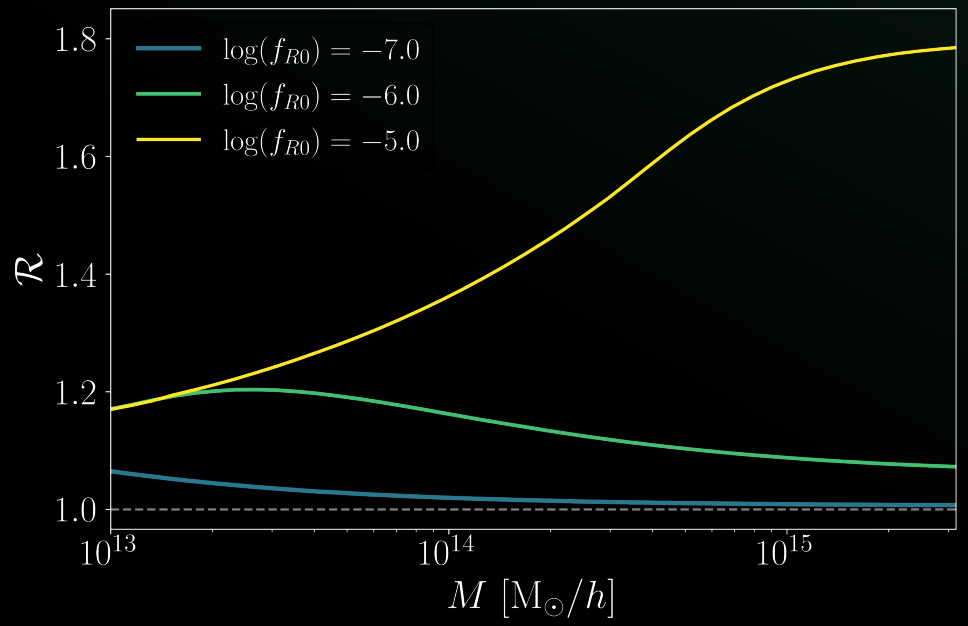
Buchdahl 1970, Schmidt+ 2009, HU&Sawicki 2007

Halo Collapse and HMF

Scale dependant δ_c



Enhancement in HMF



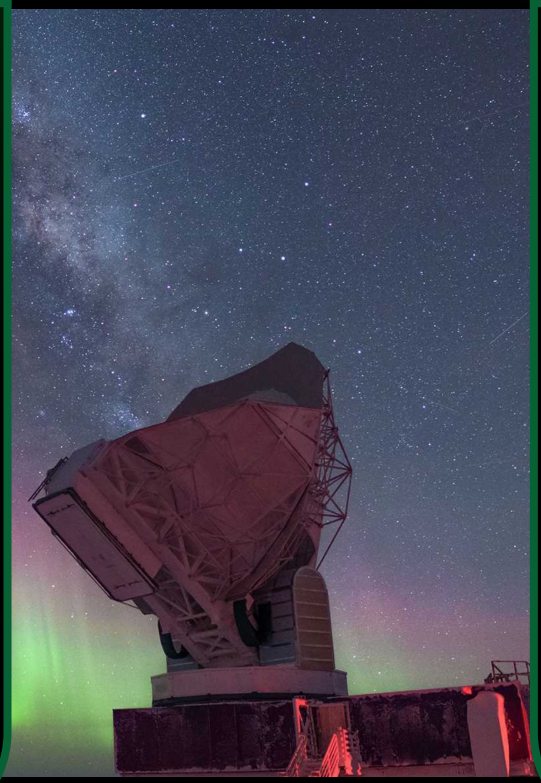
Li+ 2011, Lombriser+ 2013

SZ Cluster Surveys

SPT-SZ, SPTpol-ECS and SPTpol-500d

- 3 surveys with SPT
- Area: 5,270 deg^2
- SNR: $\xi > 4.5$, $\xi > 5$ and $\xi > 4.25$
- Redshift: $0.25 < z < 1.78$

Number of clusters in ΛCDM ~1000



CMB-S4

- StageIV futuristic survey
- Area: ~21,000 deg^2
  - Euclid overlap: ~10,100 deg^2
- SNR: $\xi > 5$
- Redshift: $0.1 < z < 2$

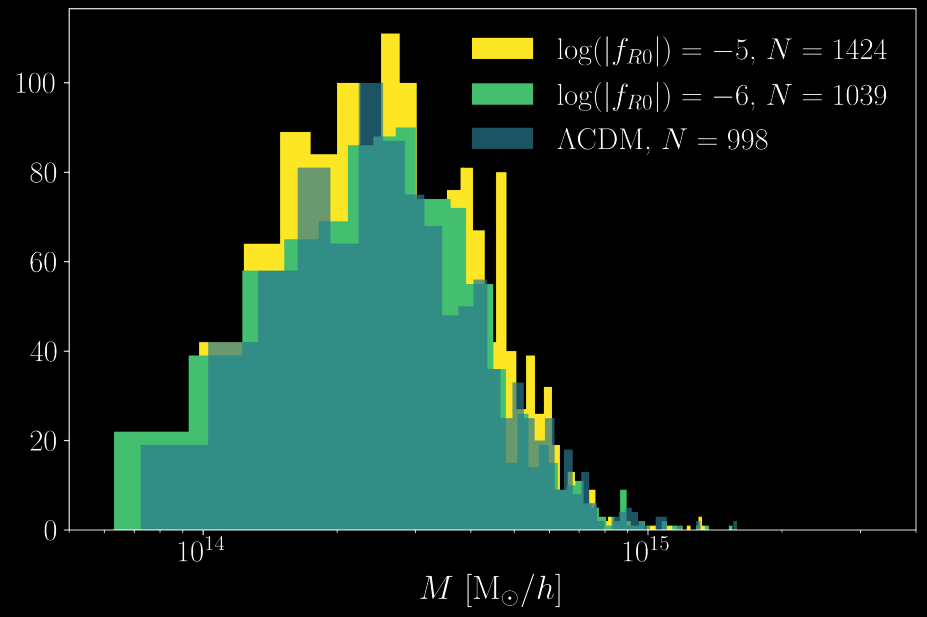
Expected number of clusters in ΛCDM ~32000

Bleem+ 2014, Bleem+ 2020, Bleem+ 2023, Raghunathan+ 2021

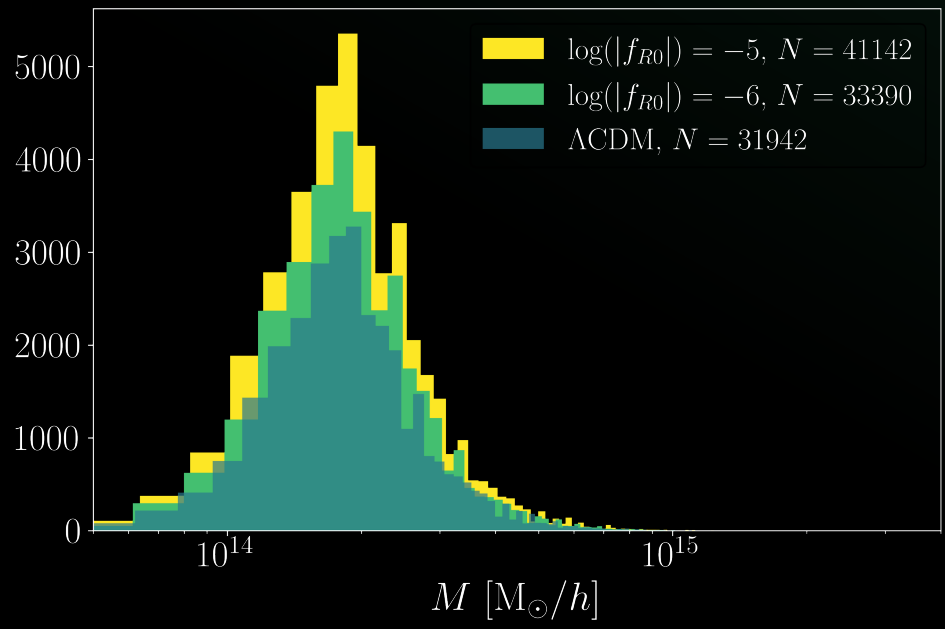
SPT and CMB-S4 Mock Catalogues

- Drawing a poisson realisation from the HMF to obtain mass and redshift
- Adding SZ observables

SPT mock



CMB-S4 mock



WL Surveys and Adding Mass Uncertanties

- Adding gaussian priors to SZ parameters to account for mass uncertanties

DES

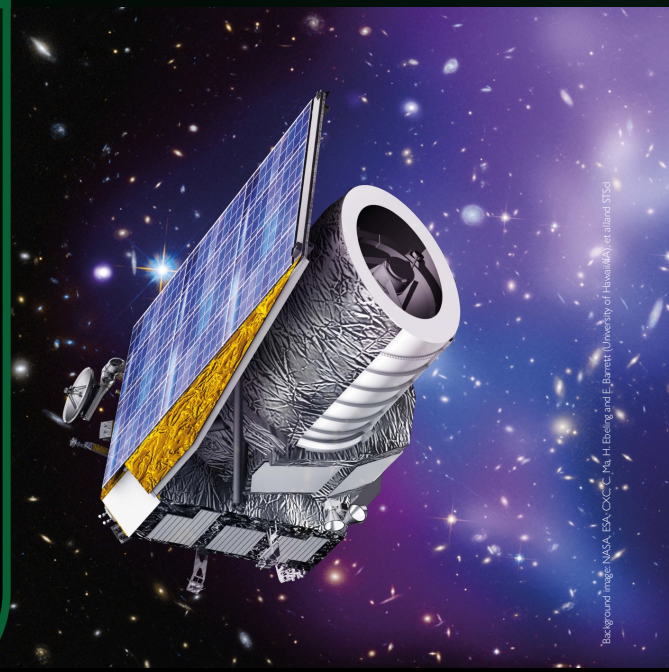
- Area: 5,000 deg^2
- 6 sources/arcmin^2
- Data exist

Constraining power is known

Euclid

- Area: 15,000 deg^2
- 30 sources/arcmin^2
- Futuristic survey, constraints has to be predicted

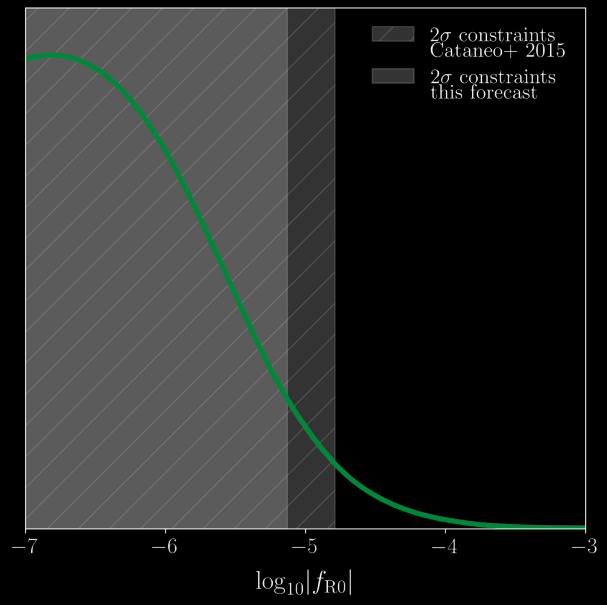
Analysis is running at the moment



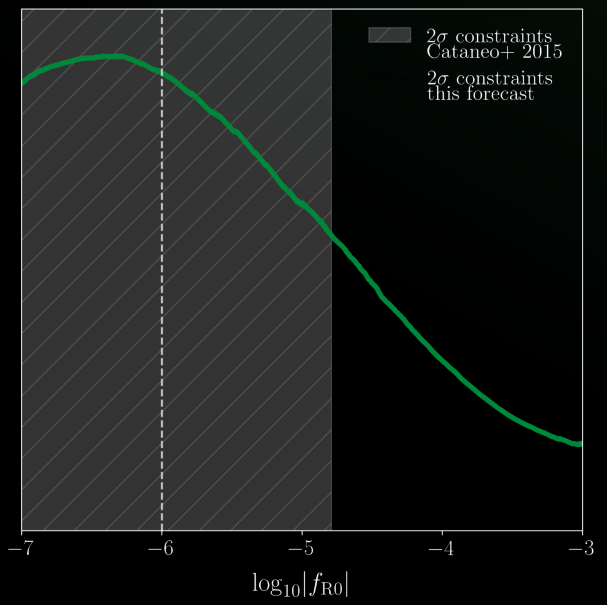
Forecasting Constraints from mockSPTxDES

- Analyse mock catalogues with different $f(R)$ parameters to see constraining power

$\log_{10}|f_{R0}| = -7$



$\log_{10}|f_{R0}| = -6$

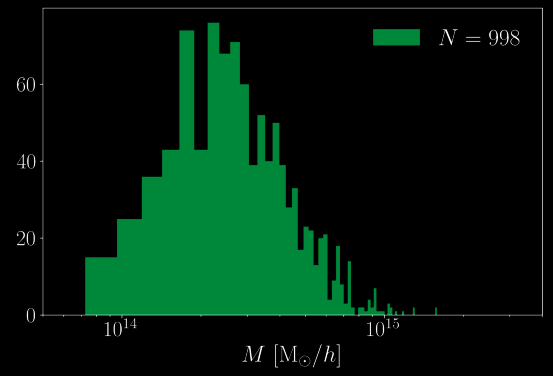


- Forecast looking promissing → apply to real SPTxDES data soon!

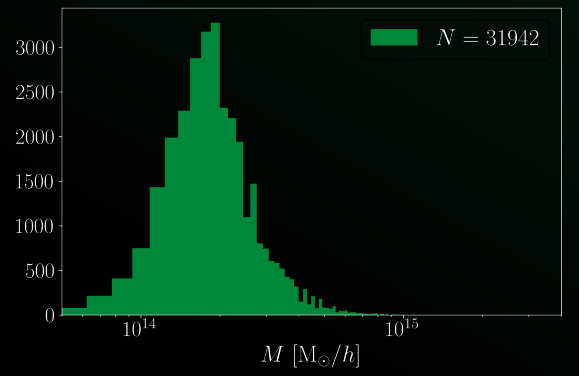
Outlook: Forecasting Constraints with CMB-S4xEuclid

- Expect much higher constraing power due to ~30x more clusters compared to SPT

SPT clusters

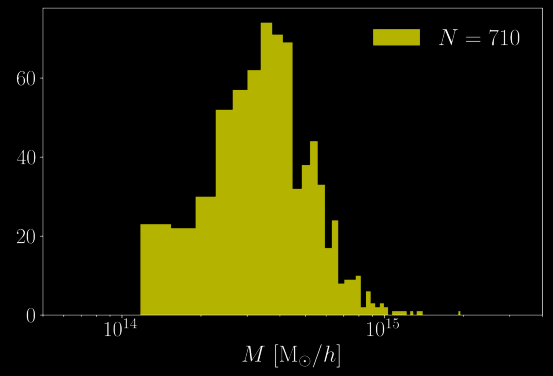


CMB-S4 clusters

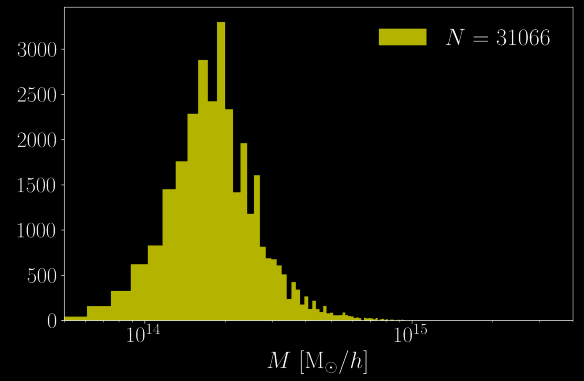


- A lot more WL data from Euclid for mass calibration

DES clusters

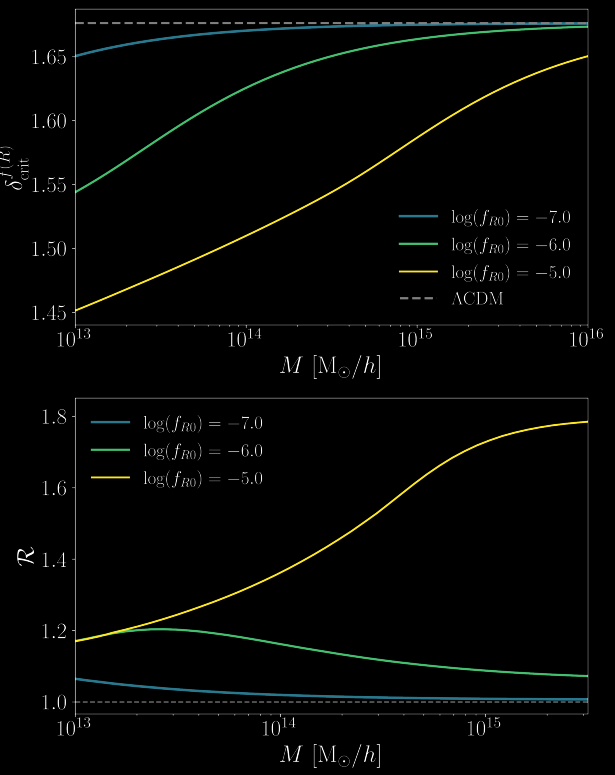


Euclid clusters

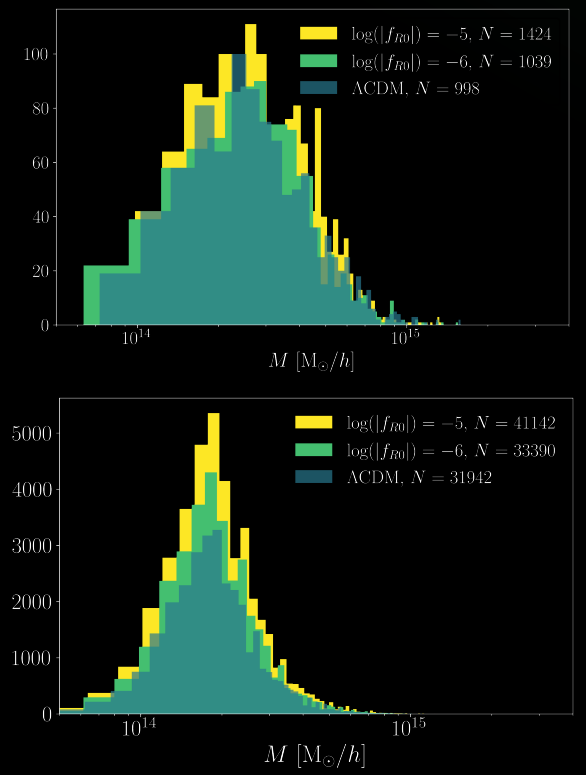


Summary

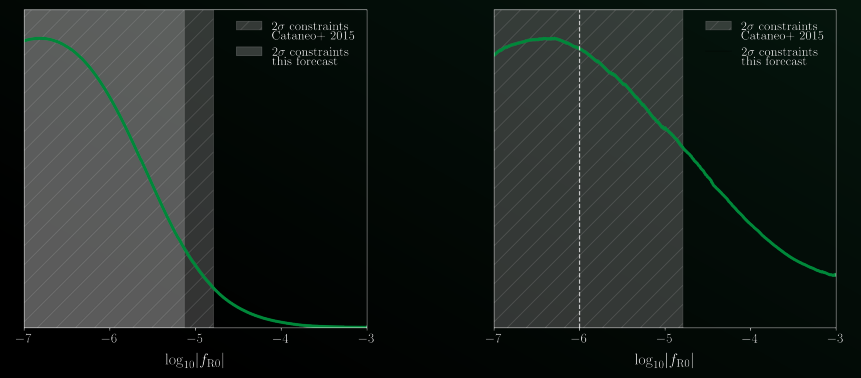
$f(R)$-gravity: scale dependent growths



Mock catalogues for SPTxDES and CMB-S4xEuclid surveys



Cluster data can tighten the constraints on $f(R)$-gravity



Analysis in progress

stronger constraints expected