Modelling baryonic effects in cosmological surveys

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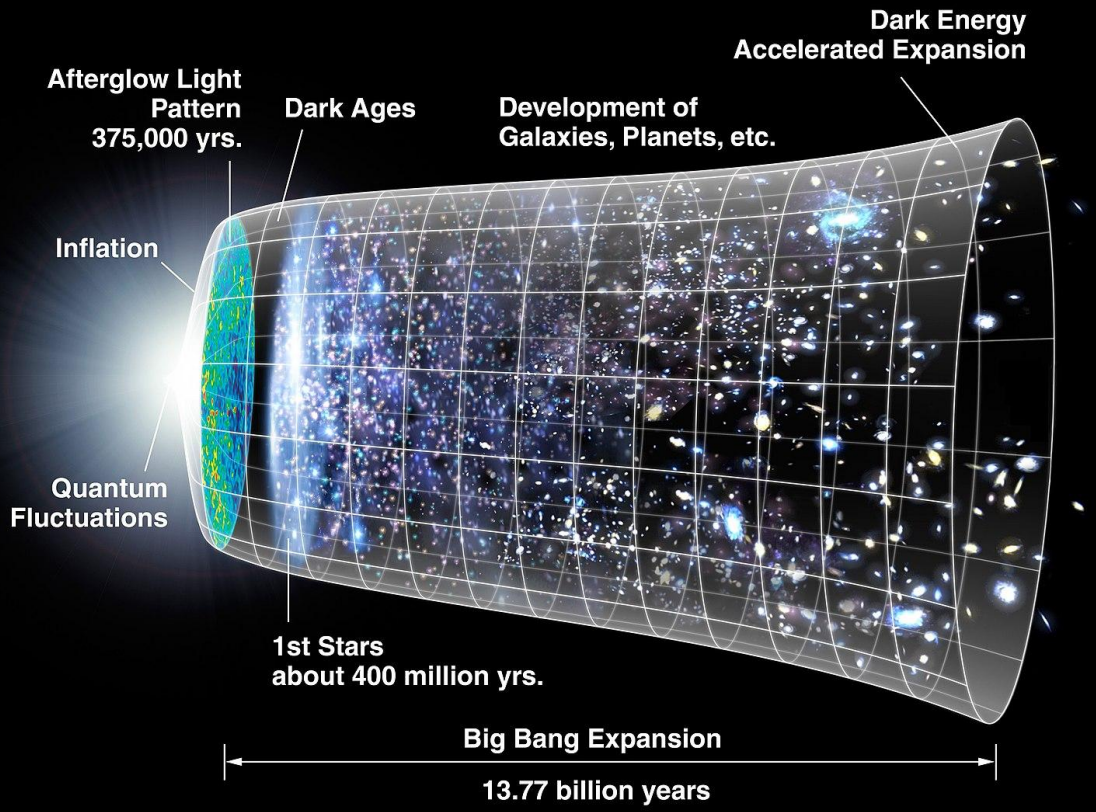
Outline

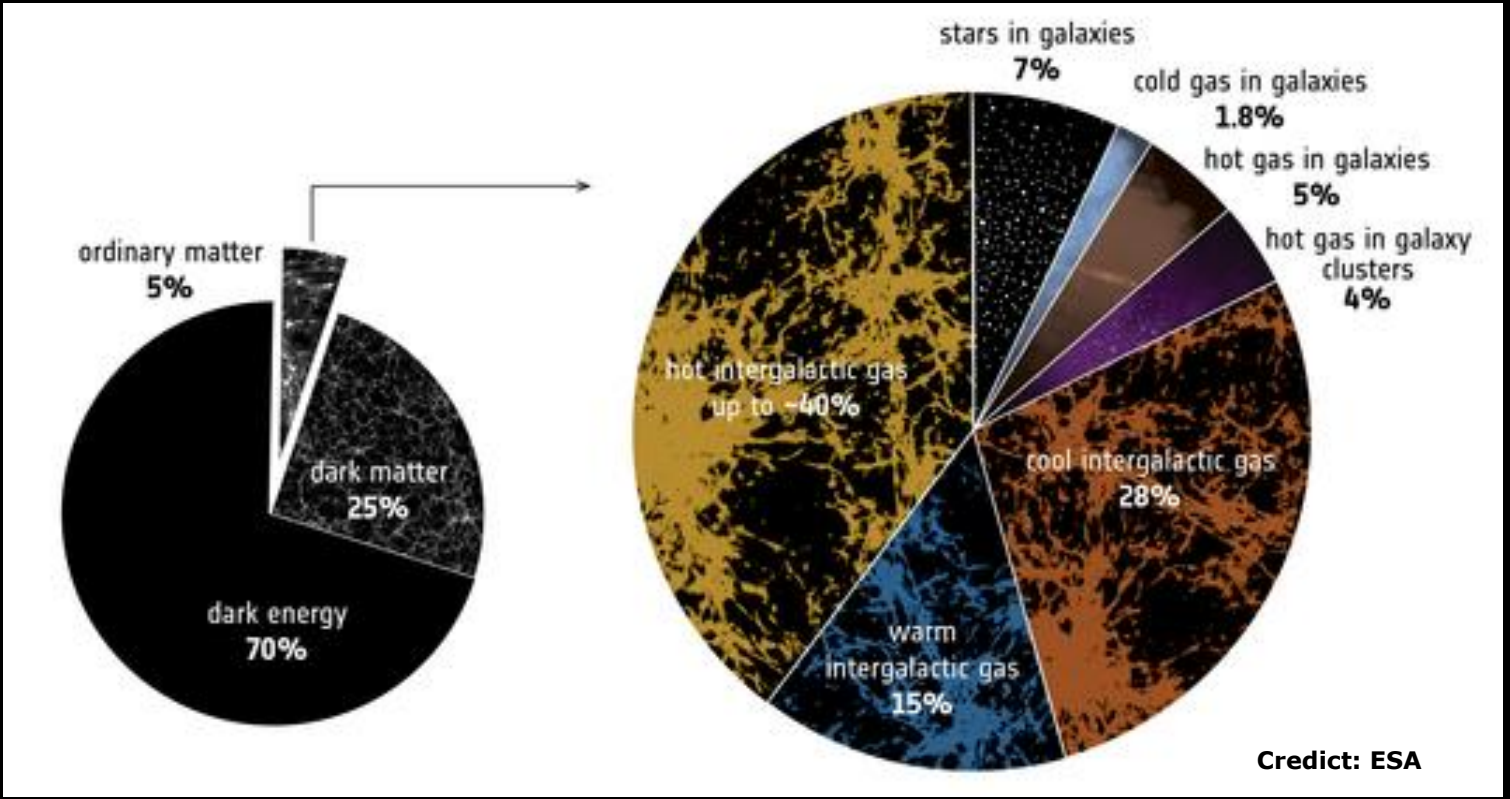
- What are baryonic effects?
- Why should we care about baryonic effects?
- Baryonification model
- Constraints on baryonic effects from observations
- Interpreting cosmological surveys

History of our Universe



Credit: NASA

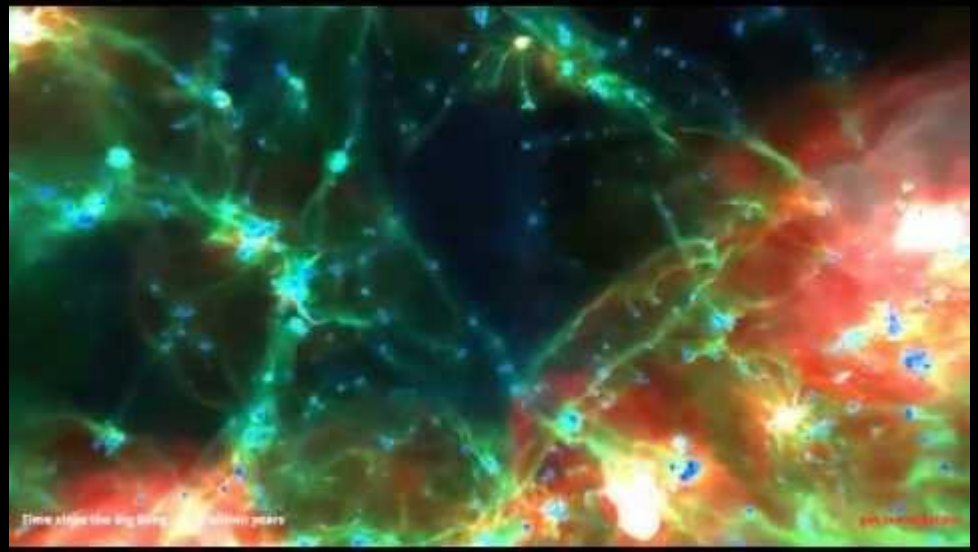
Cosmic baryon budget



A Flight Through the Universe (Sloan Digital Sky Survey)

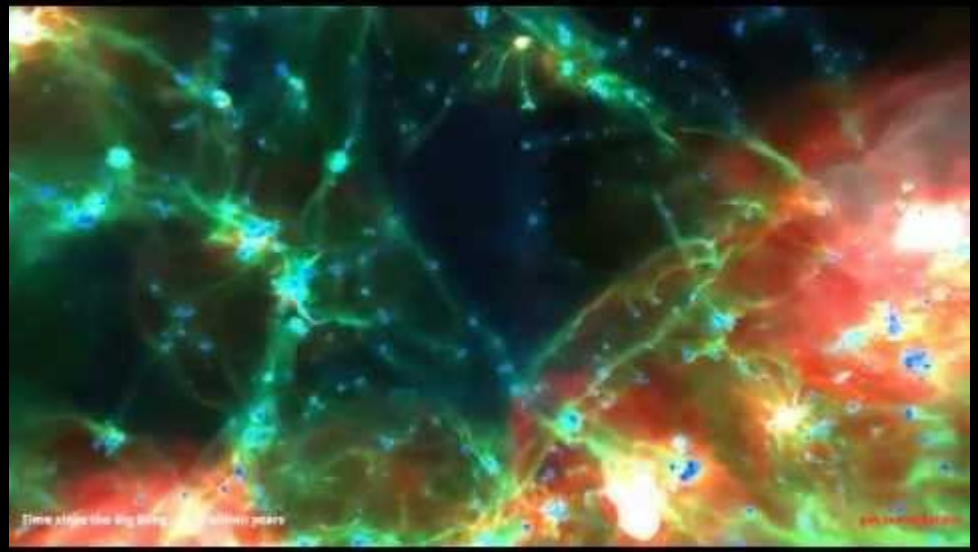
Credit:
Aragon,
Subbarao,
Szalay

Evolution of structures in our universe



Illustris simulation
(e.g. Vogelsberger+2014)

What are baryonic effects?



Illustris simulation
(e.g. Vogelsberger+2014)

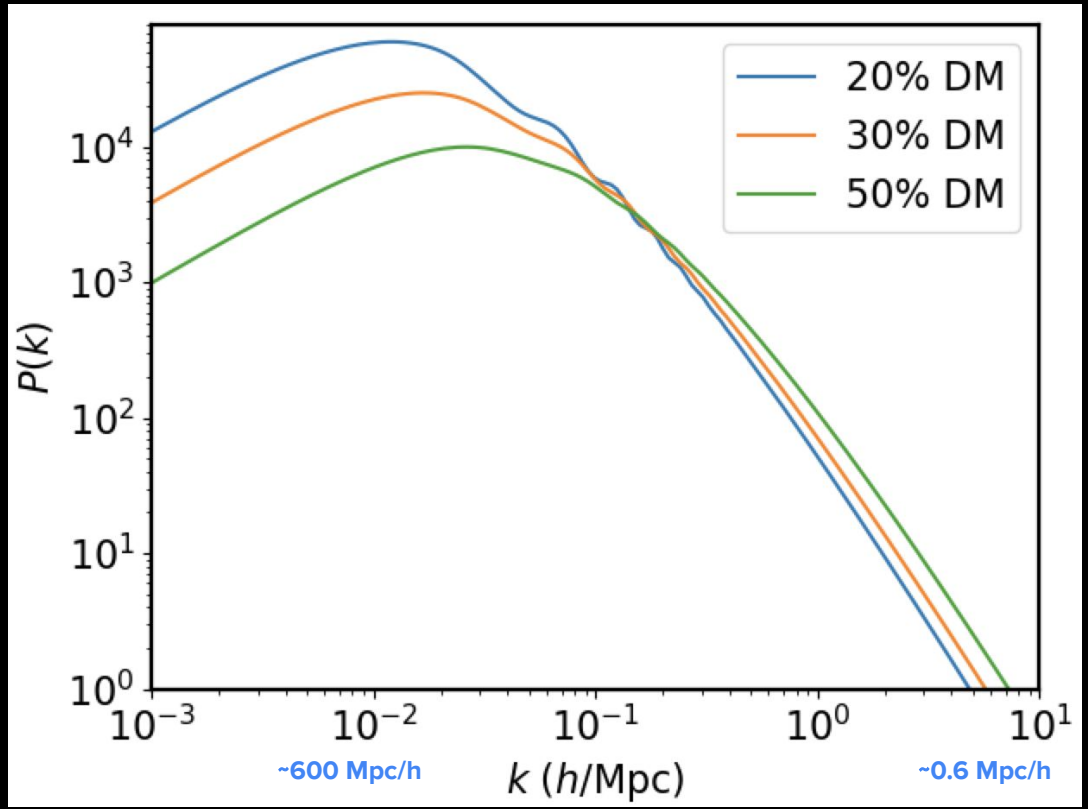
Matter in our universe

Illustris simulation

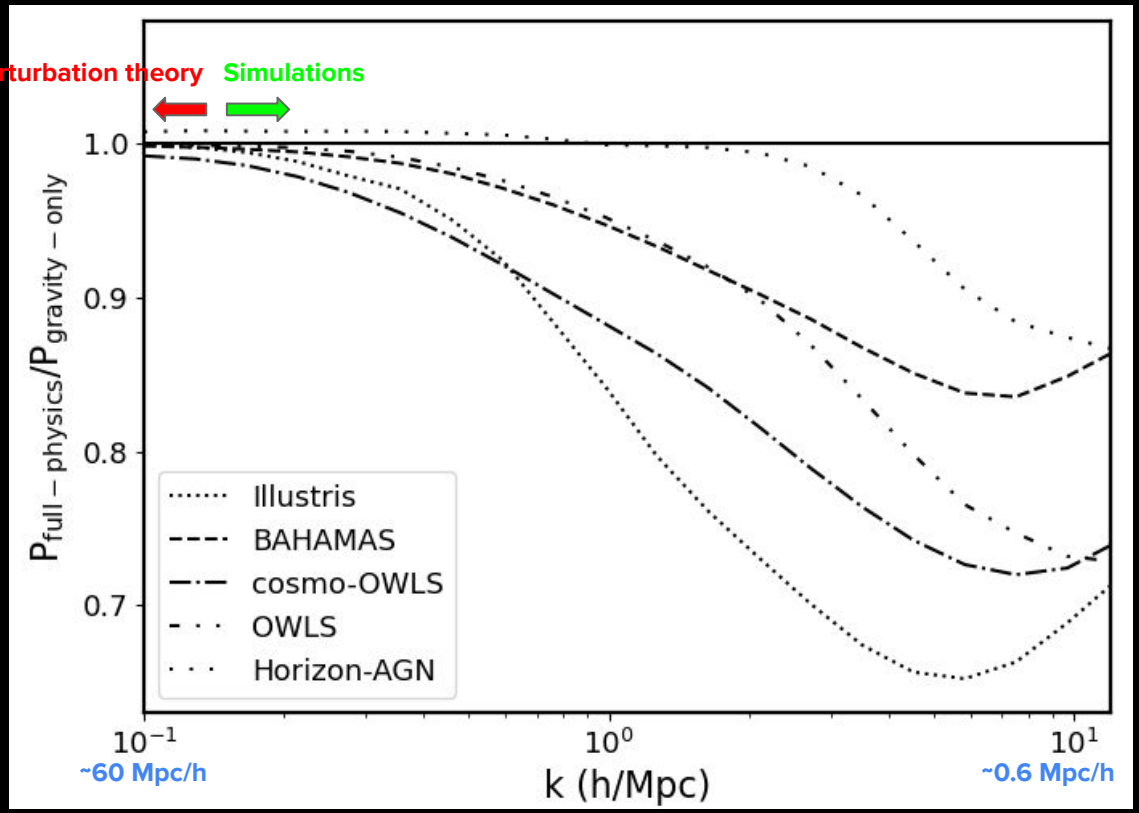
Dark Matter

Baryons

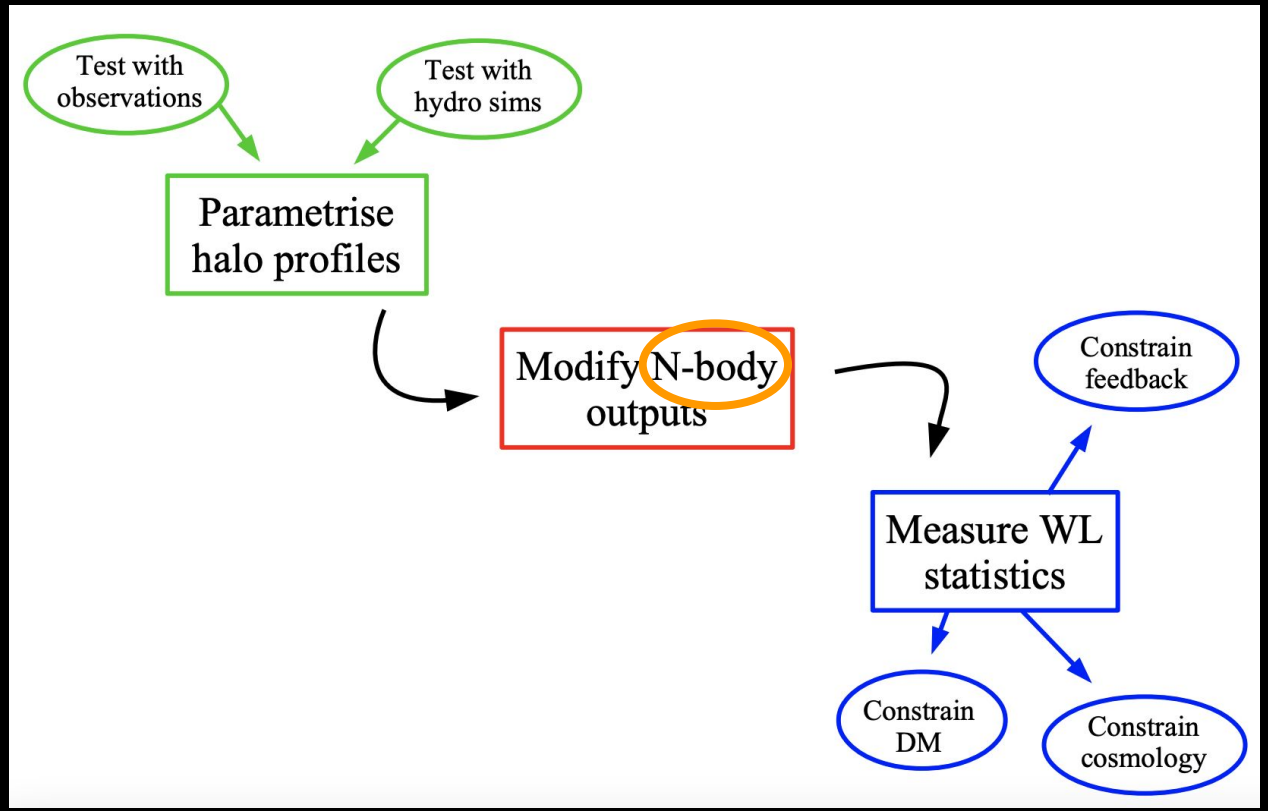
Metric to measure cosmology



Why should we care about baryonic effects?

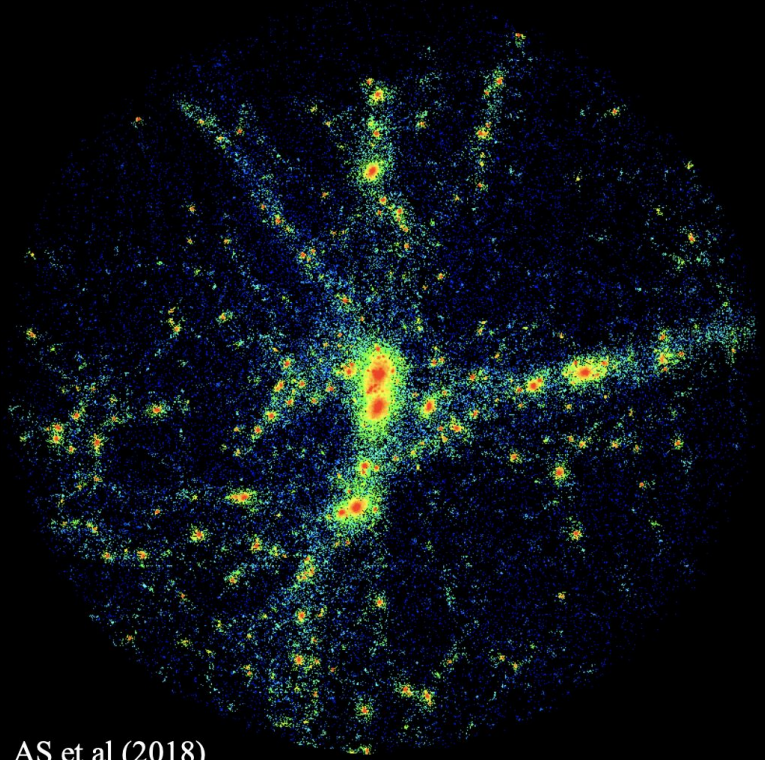


Baryonication model



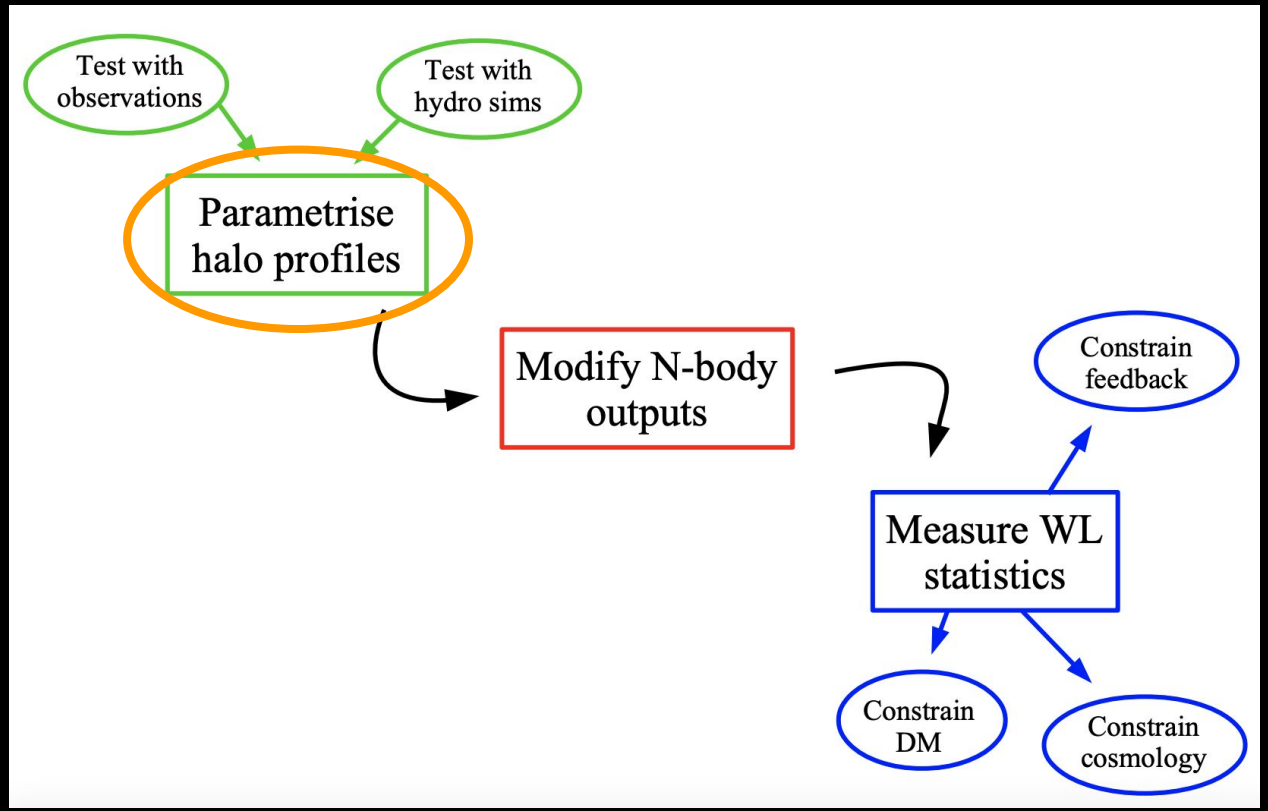
Credit: Aurel

N-body simulation of evolution of dark matter



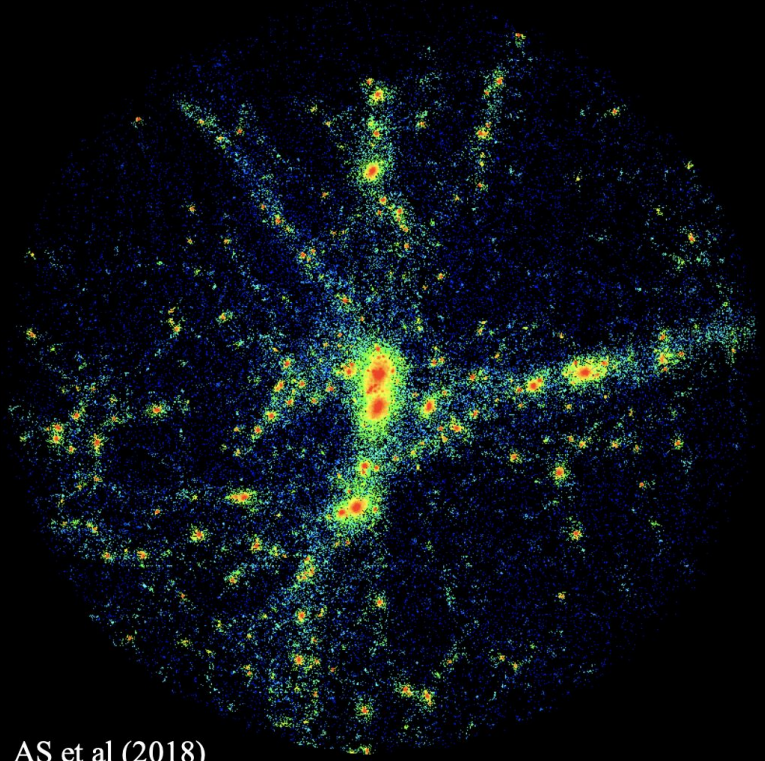
AS et al (2018)

Baryonication model

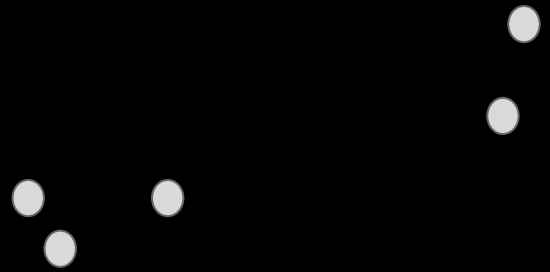


Credit: Aurel

Finding halos



AS et al (2018)



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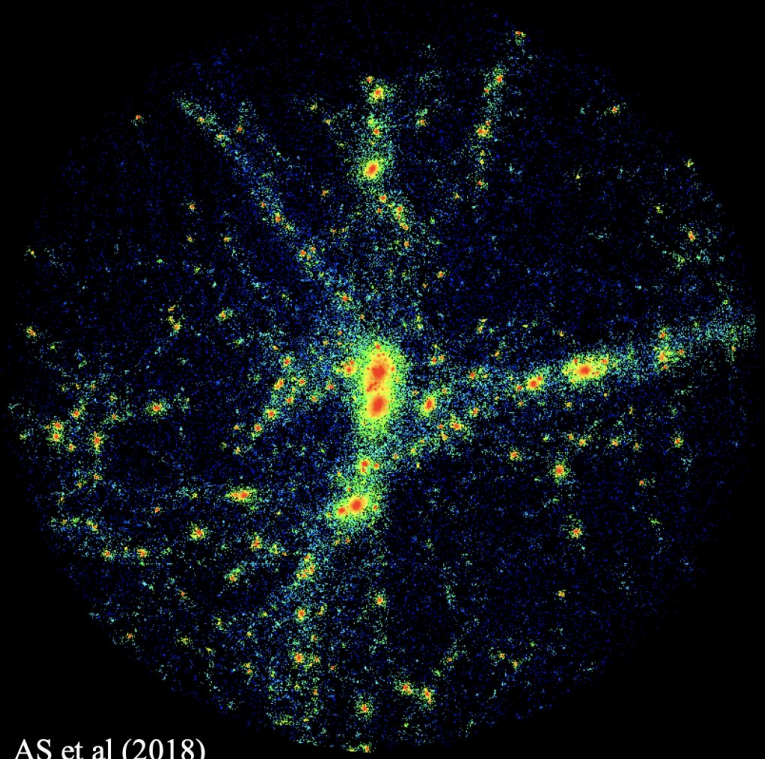
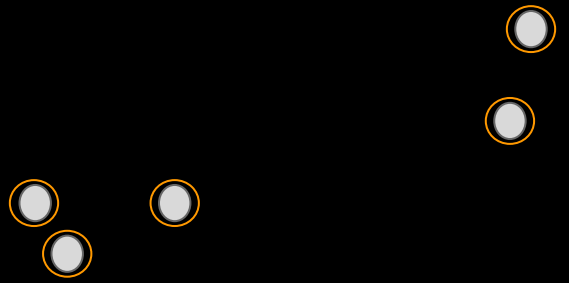


AS et al (2018)



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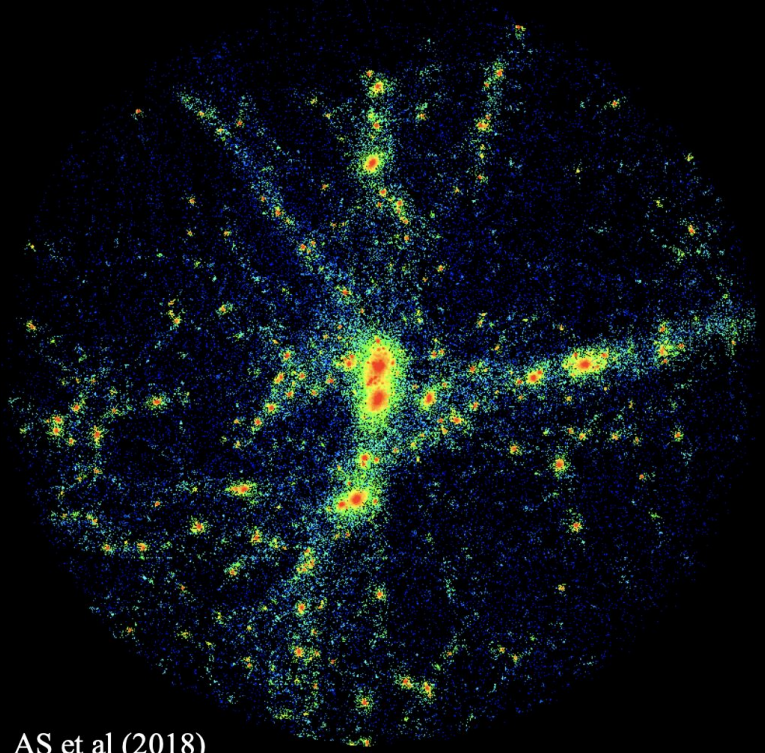
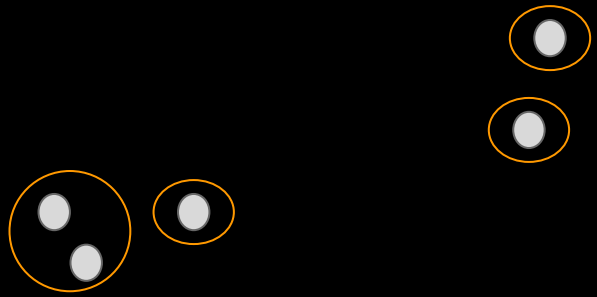
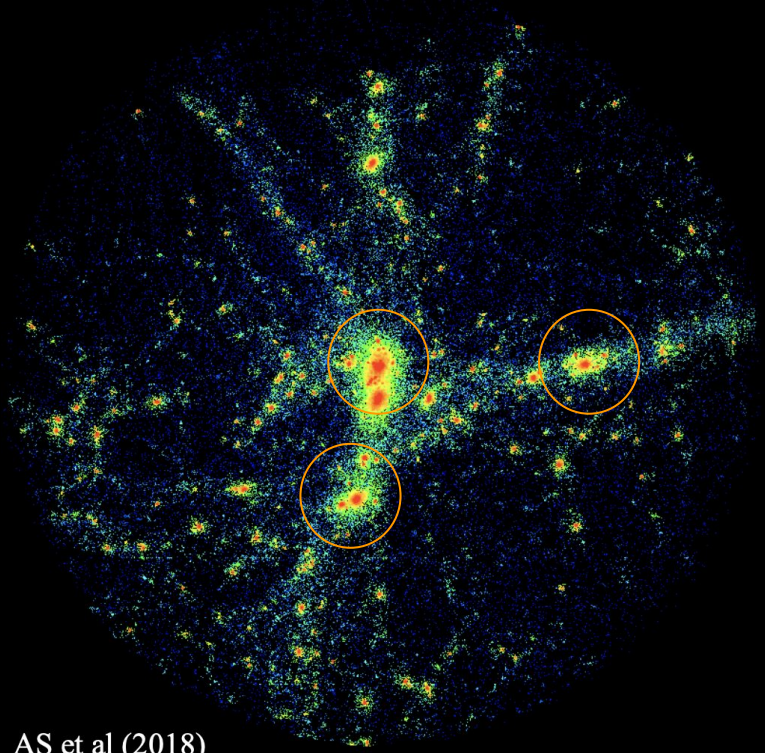


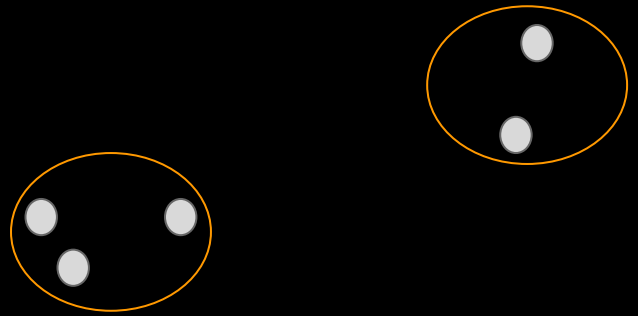
AS et al (2018)



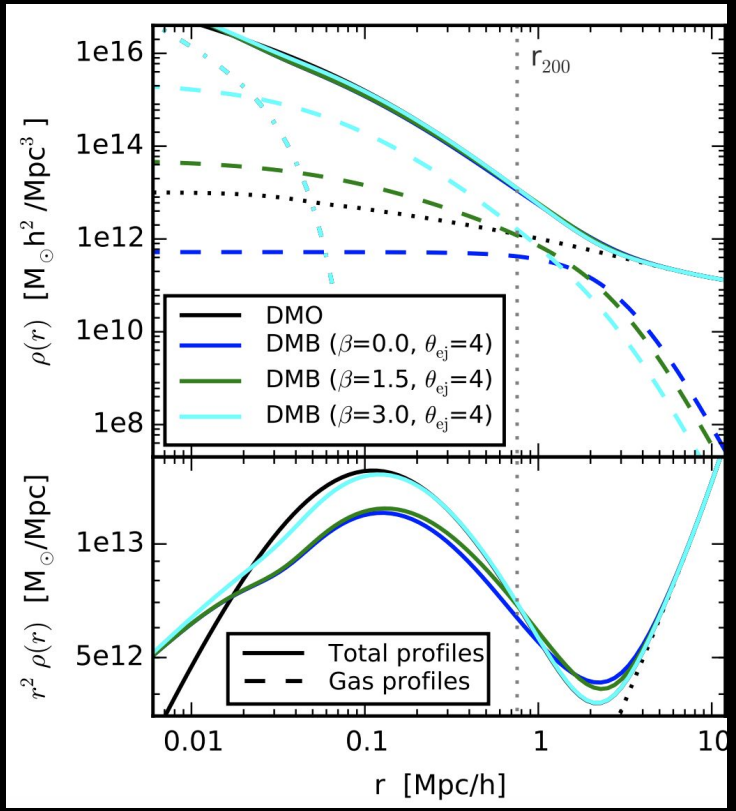
Finding halos



AS et al (2018)

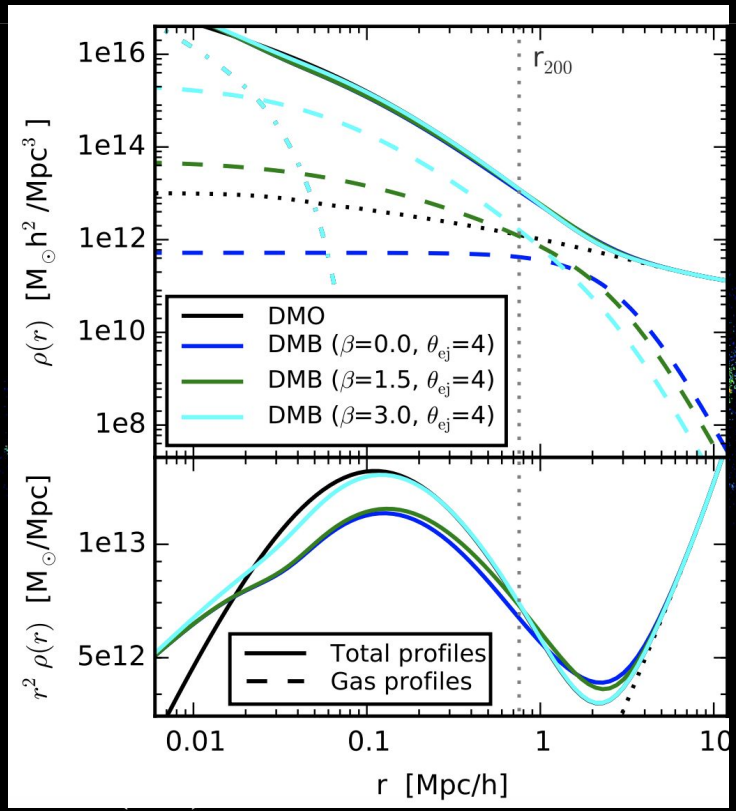


Effects on halo profiles



Schneider+2018

Transform the halo profiles



$$\rho_{\rm nfw}(r) \rightarrow \rho_{\rm dmb}(r) = \rho_{\rm clm}(r) + \rho_{\rm gas}(r) + \rho_{\rm stars}(r)$$

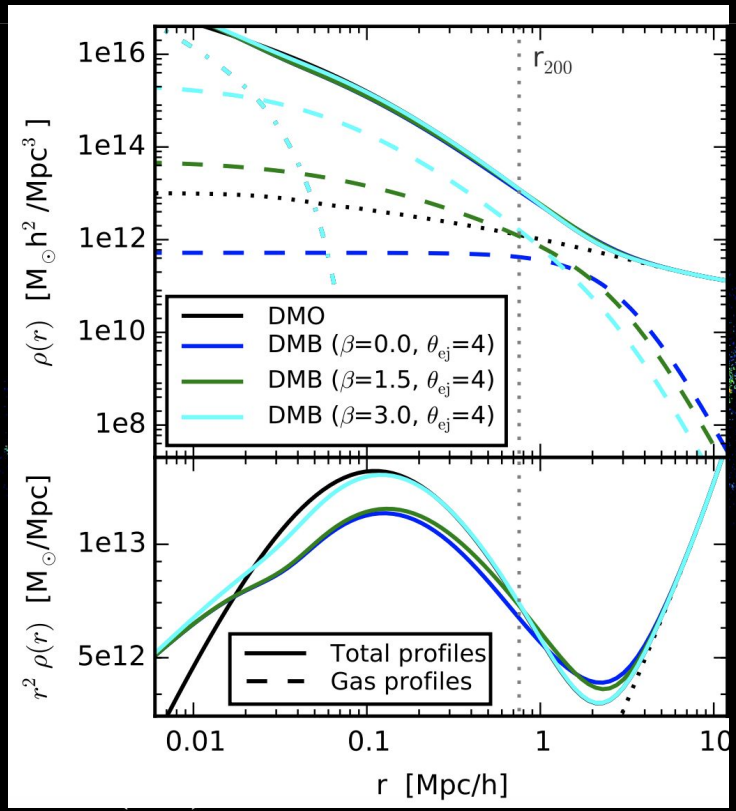
$$\rho_{\rm clm}(r) \propto \rho_{\rm nfw}(r)$$

$$\rho_{\rm star}(r) \propto \frac{1}{r^2 M^\eta} \exp\left[-\left(\frac{r}{2R_{\rm h}}\right)^2\right]$$

$$\rho_{\rm gas}(r) \propto \left[1 + 10\left(\frac{r}{r_{\rm vir}}\right)\right]^{-\beta(M)} \left[1 + \left(\frac{r}{\theta_{\rm ej} r_{\rm vir}}\right)^\gamma\right]^{\frac{\beta(M)-\delta}{\gamma}}$$

$$\beta(M) = \frac{3(M_c/M)^\mu}{1 + (M_c/M)^\mu}$$

Baryonic parameters



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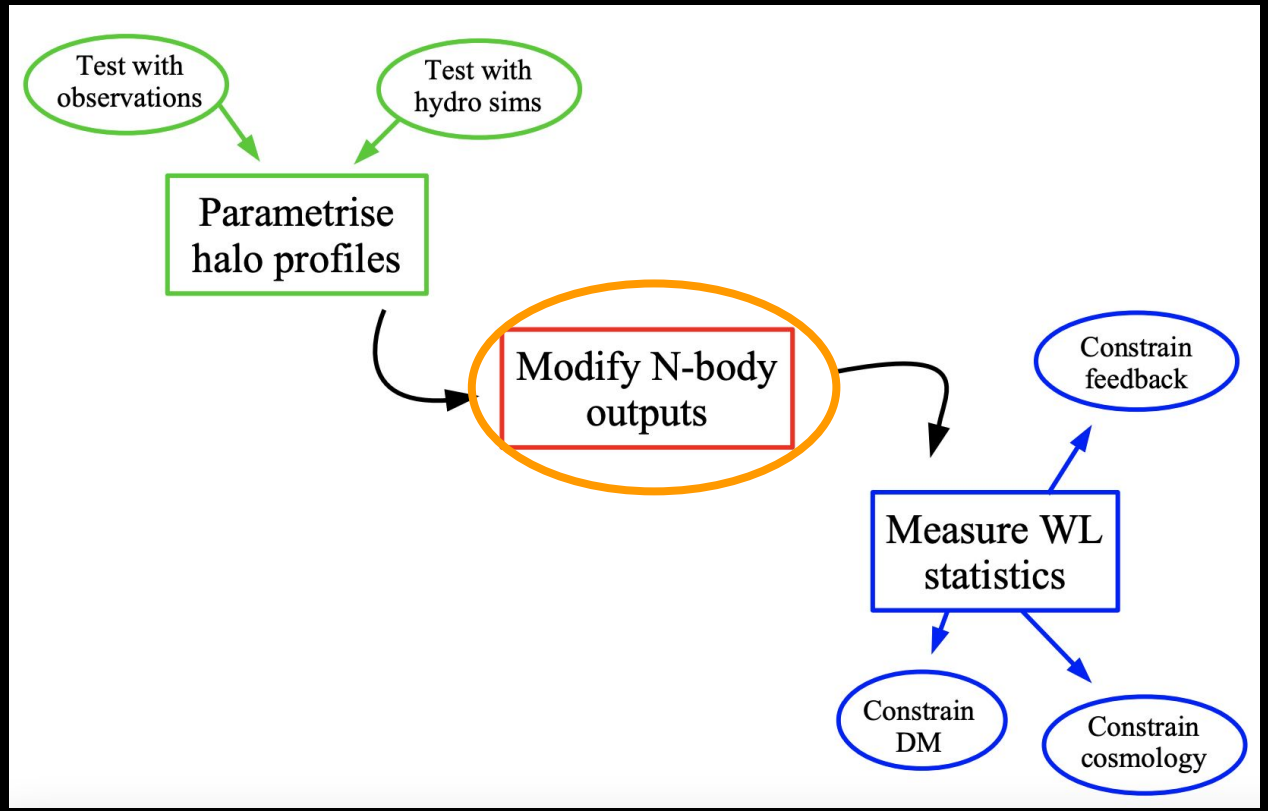
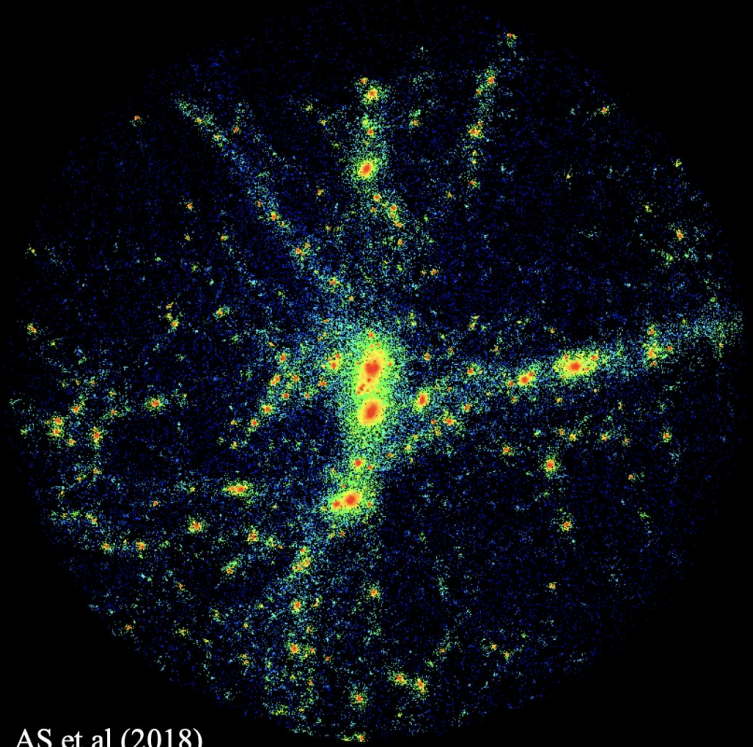
Baryonication model



Credit: Aurel

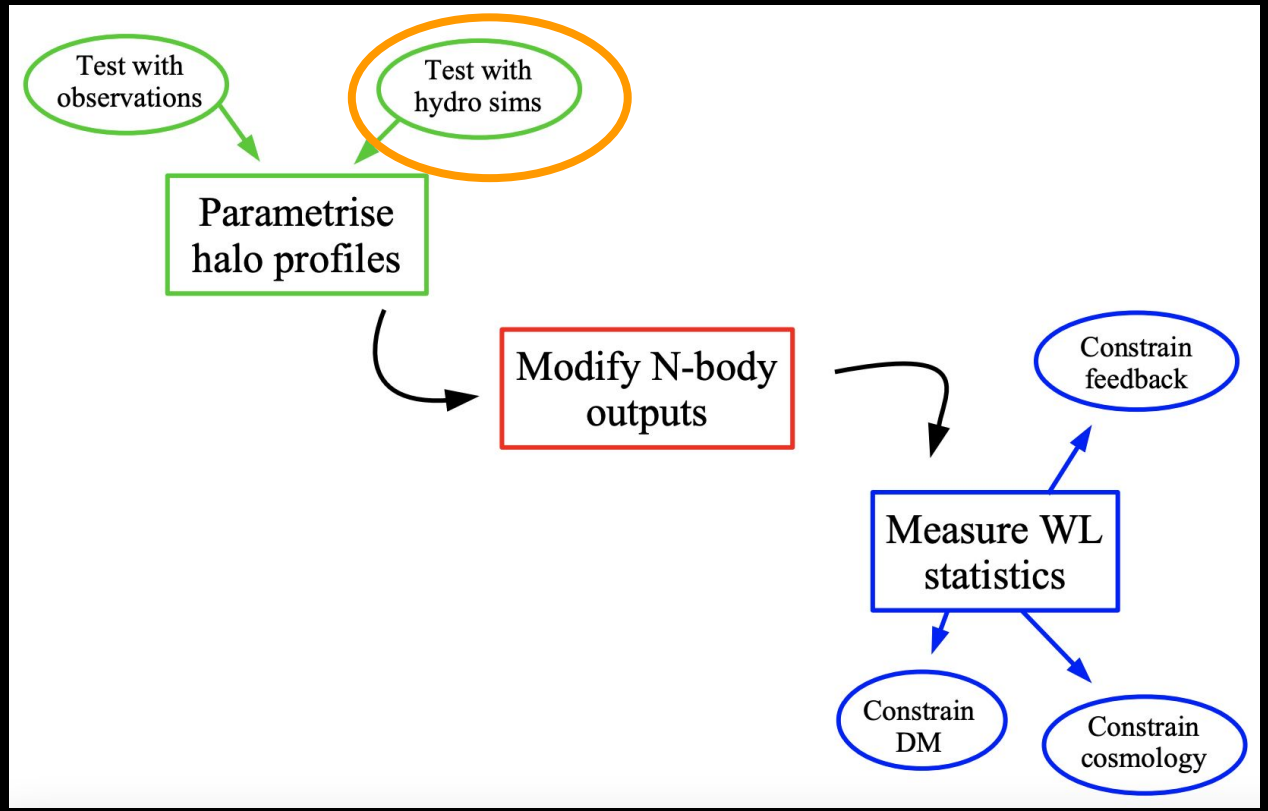
Modify the N-body simulations



AS et al (2018)

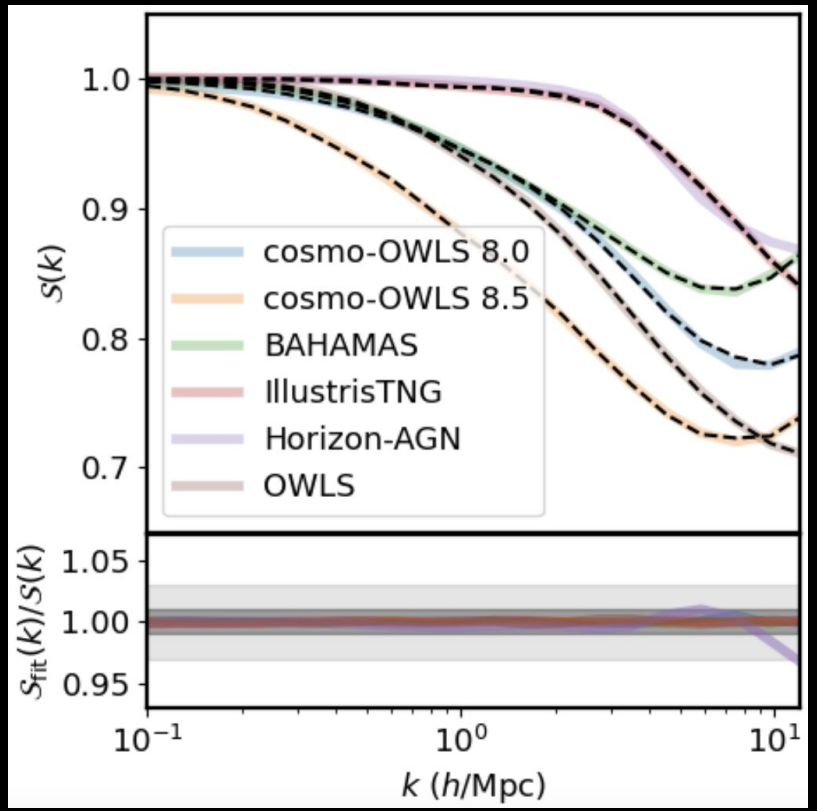
$$\rho_{\rm dmo}(r) \rightarrow \rho_{\rm dmb}(r) = \rho_{\rm clm}(r) + \rho_{\rm gas}(r) + \rho_{\rm stars}(r)$$

Baryonication model



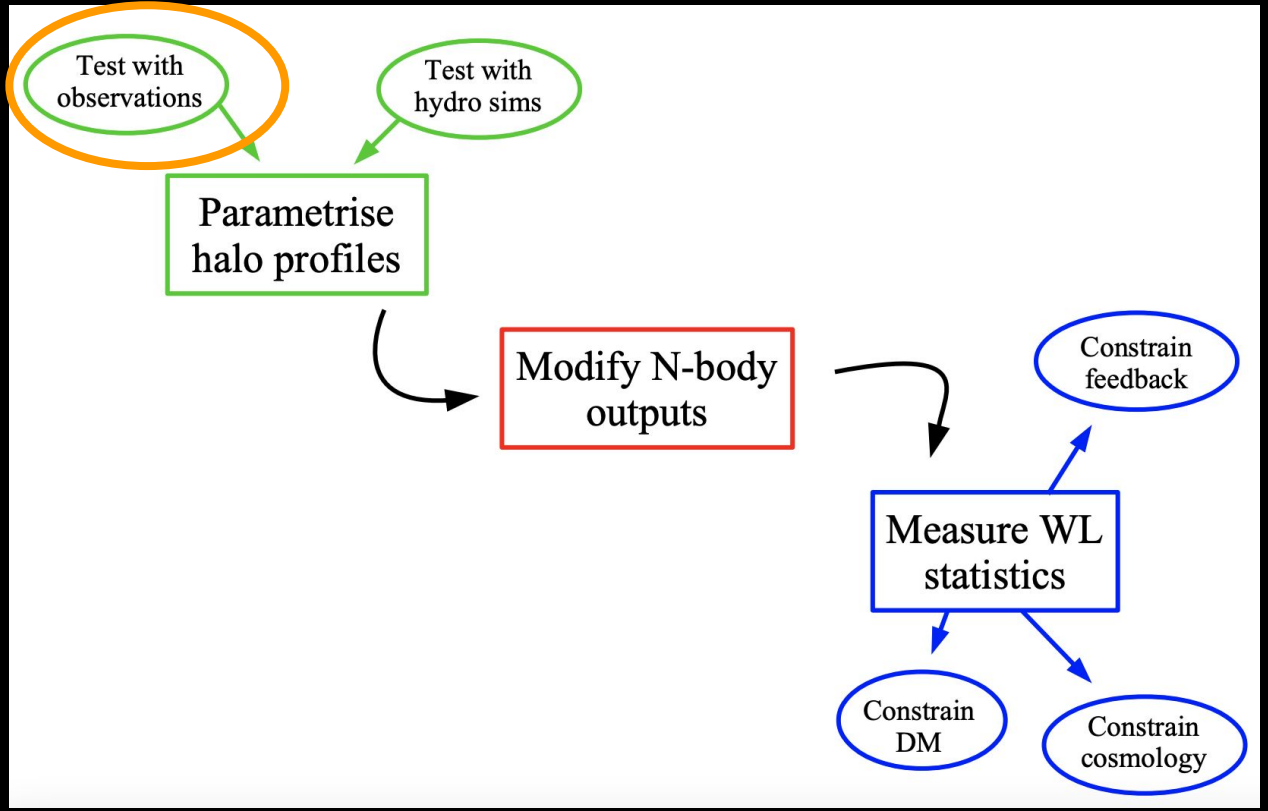
Credit: Aurel

Reproduction of the baryonic suppression



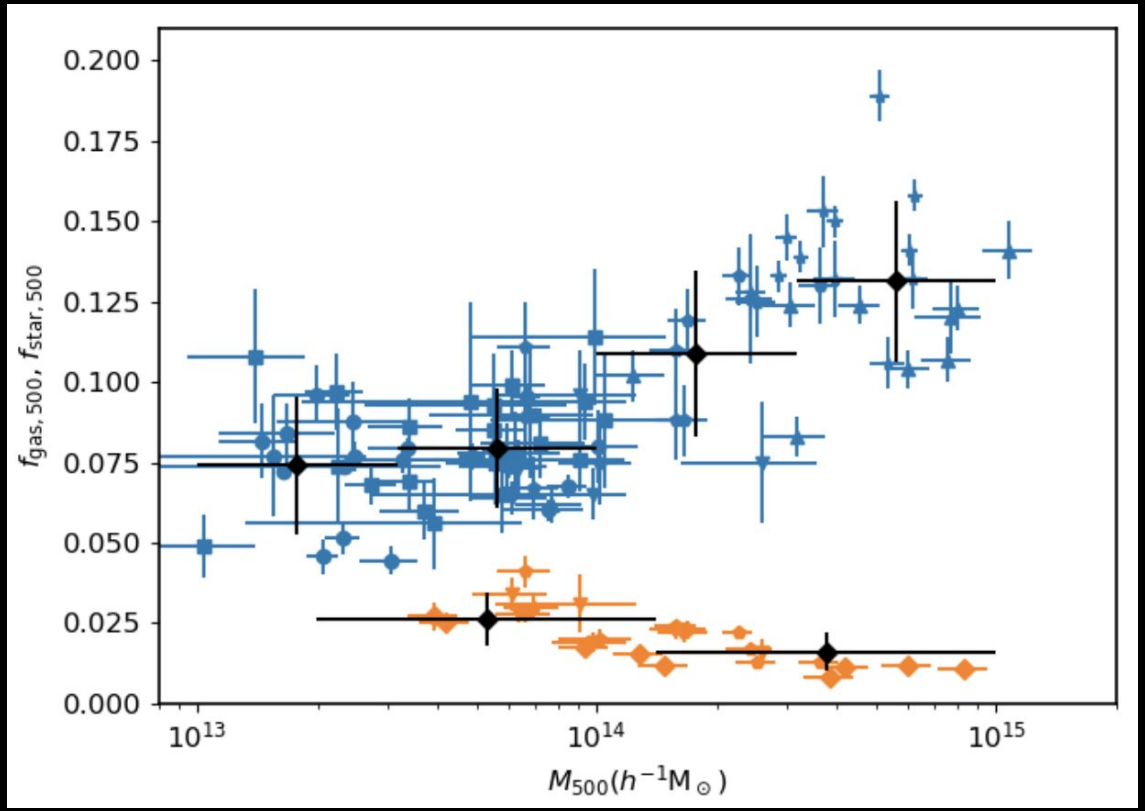
Giri & Schneider (2021)

Baryonication model



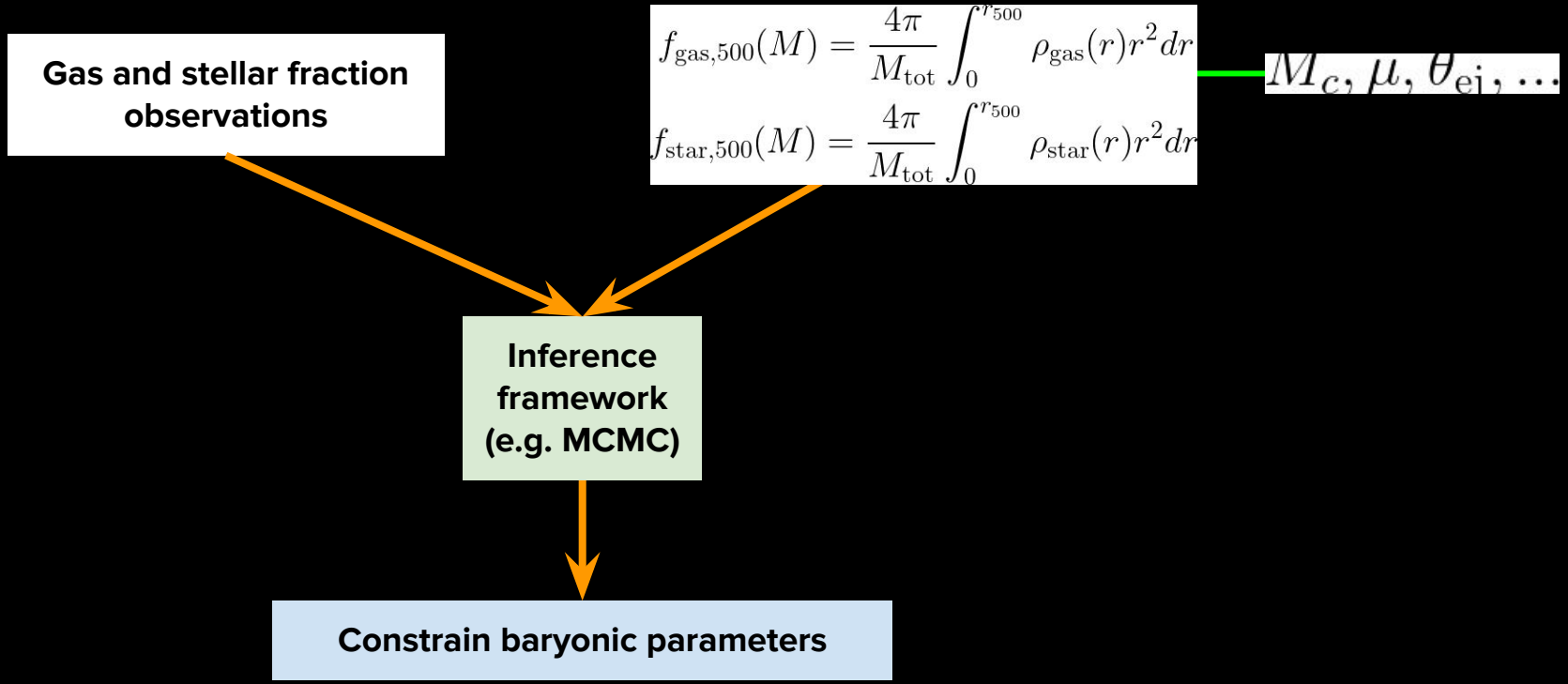
Credit: Aurel

Observation of galaxy clusters

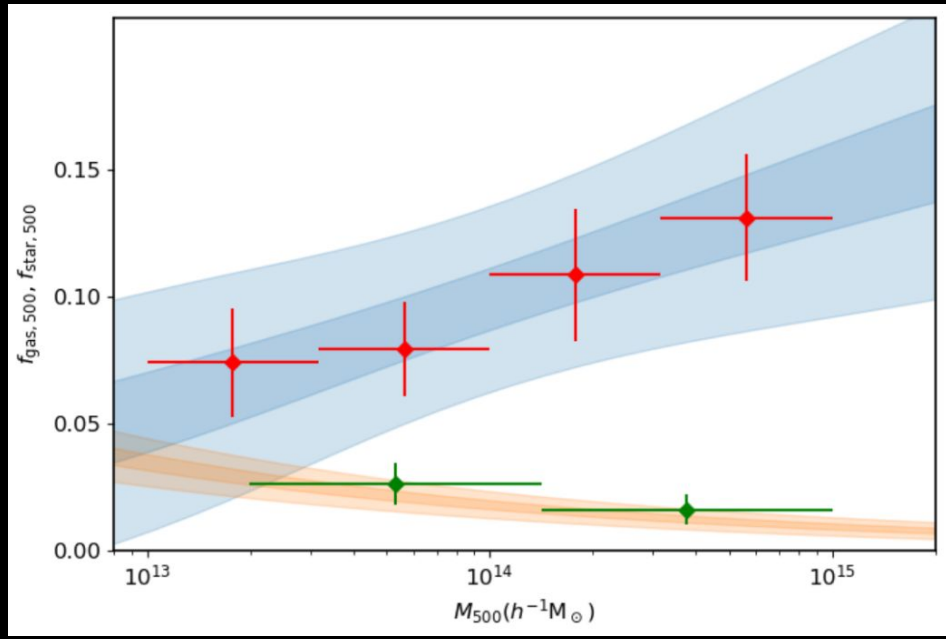


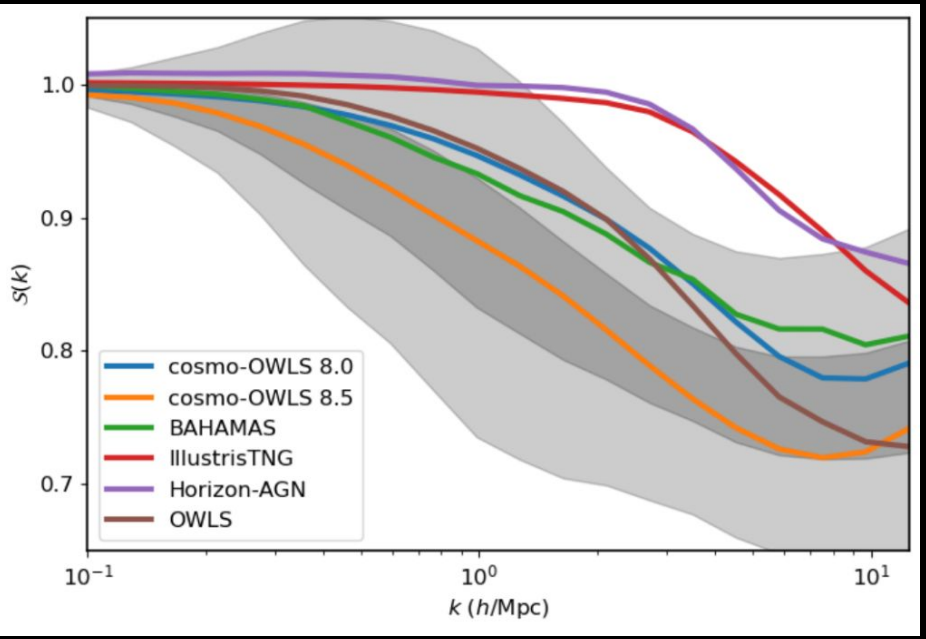
Kravtsov+2018
Vikhlinin+2006
Gonzalez+2013
Sanderson+2013
Lovisari+2015

Parameter estimation



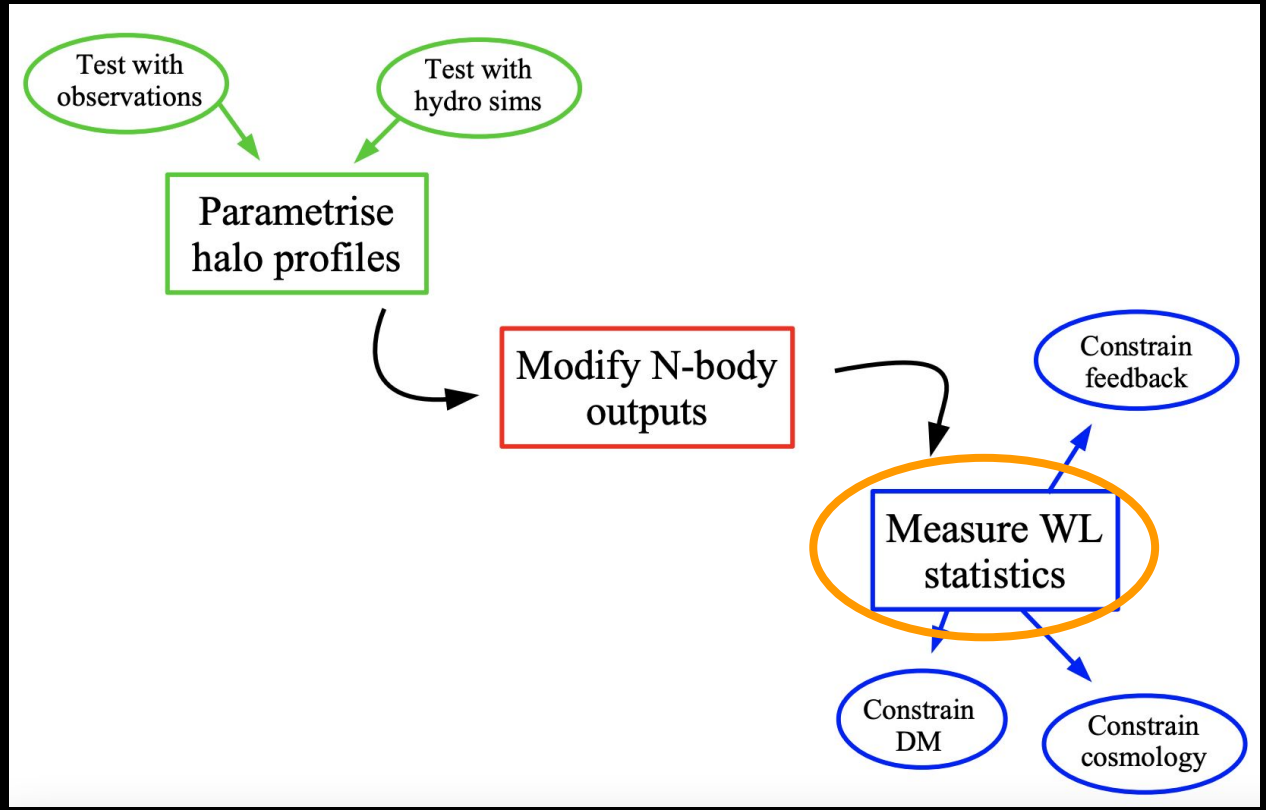
Constraints on baryonic effects





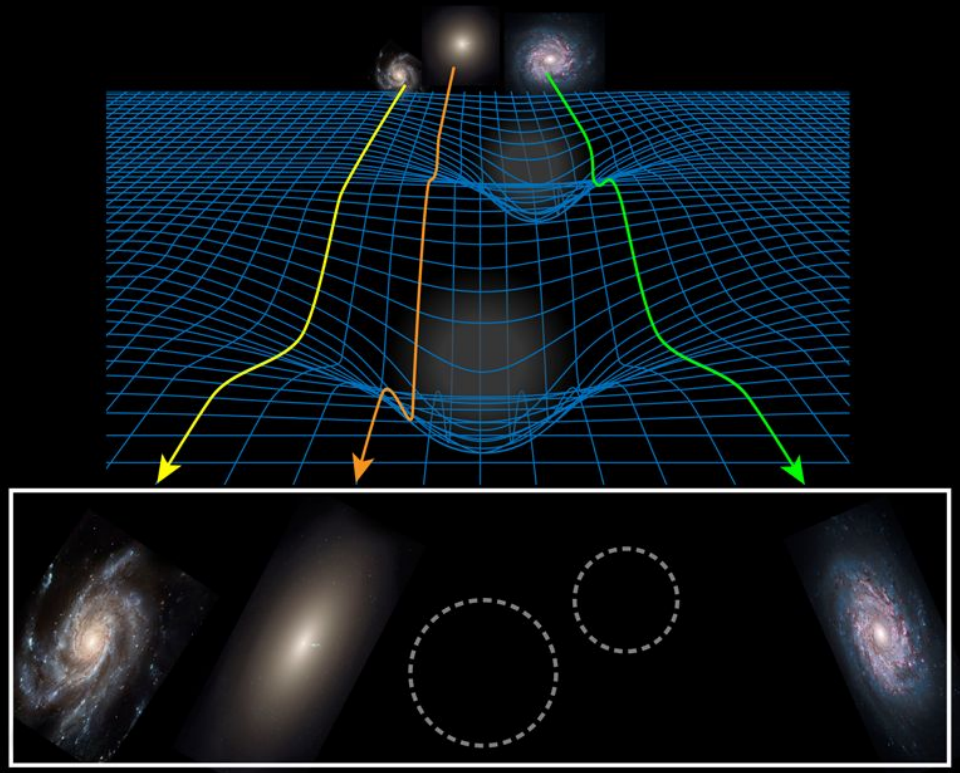
Giri & Schneider (2021)

Baryonication model



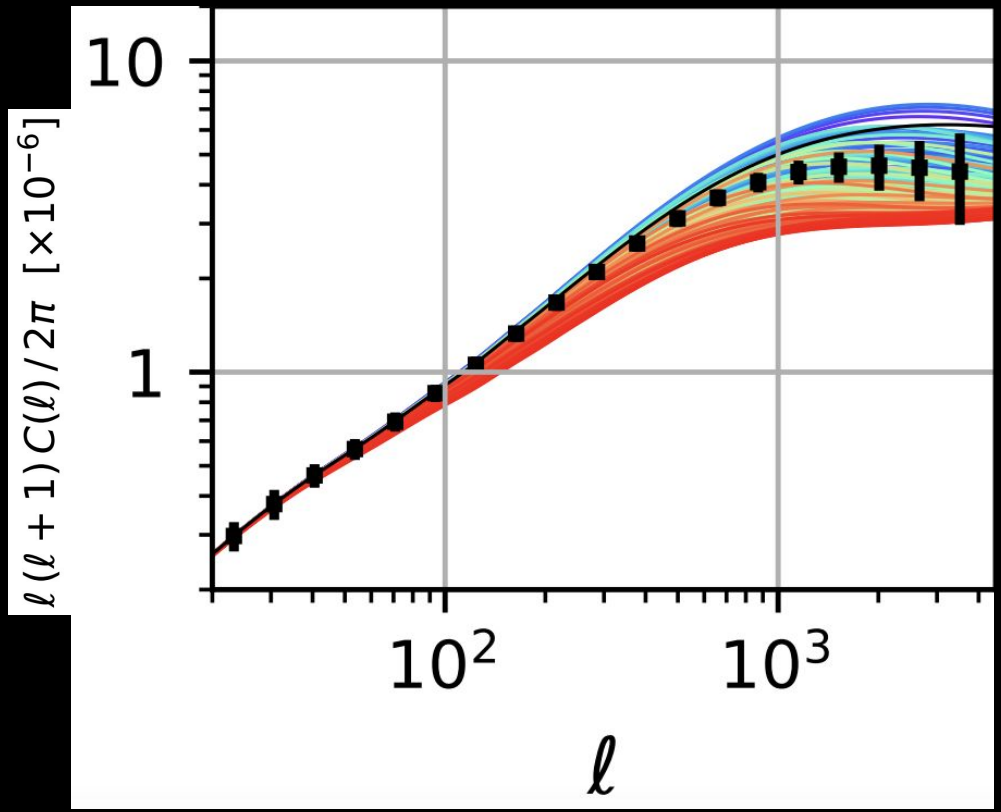
Credit: Aurel

Weak-lensing



APS: Stonebracker

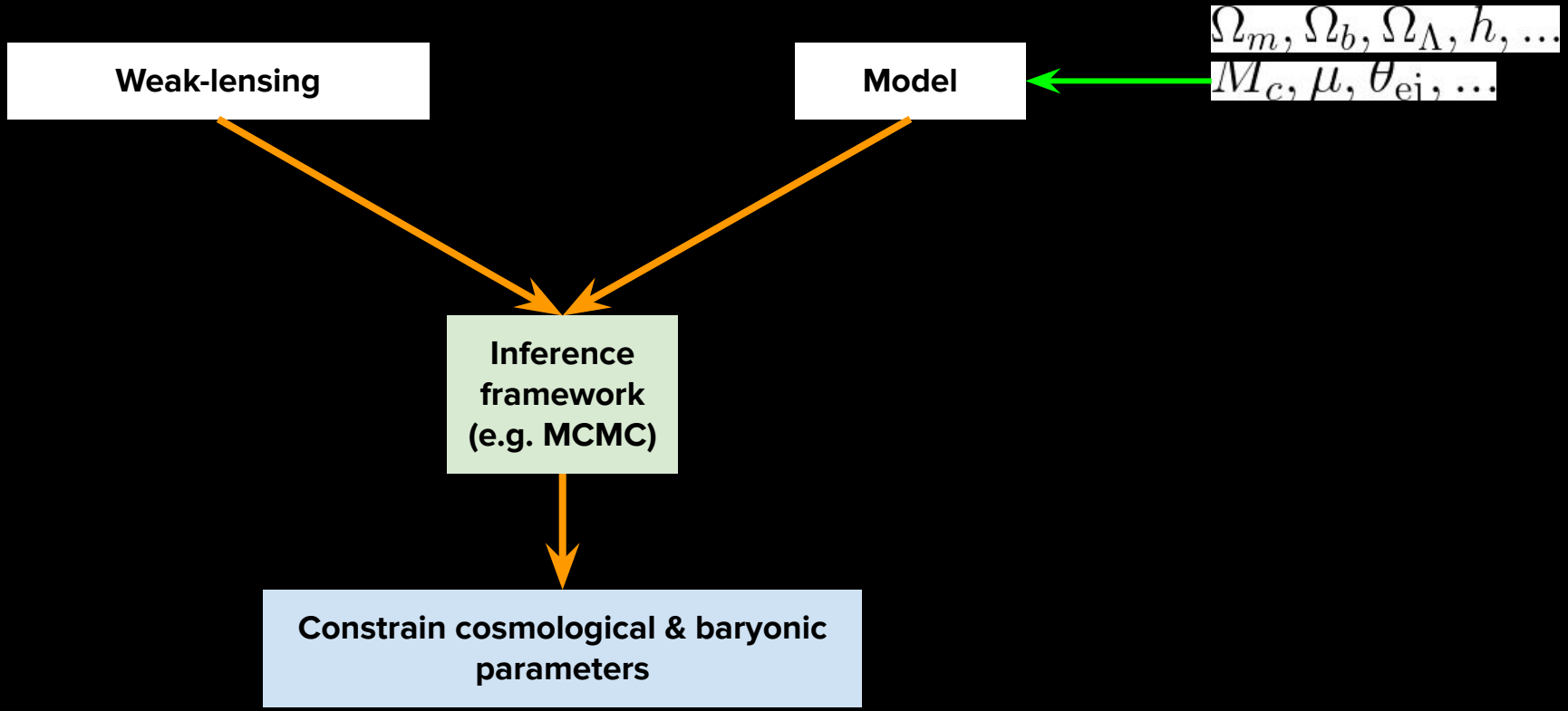
Euclid-like weak-lensing shear power spectrum



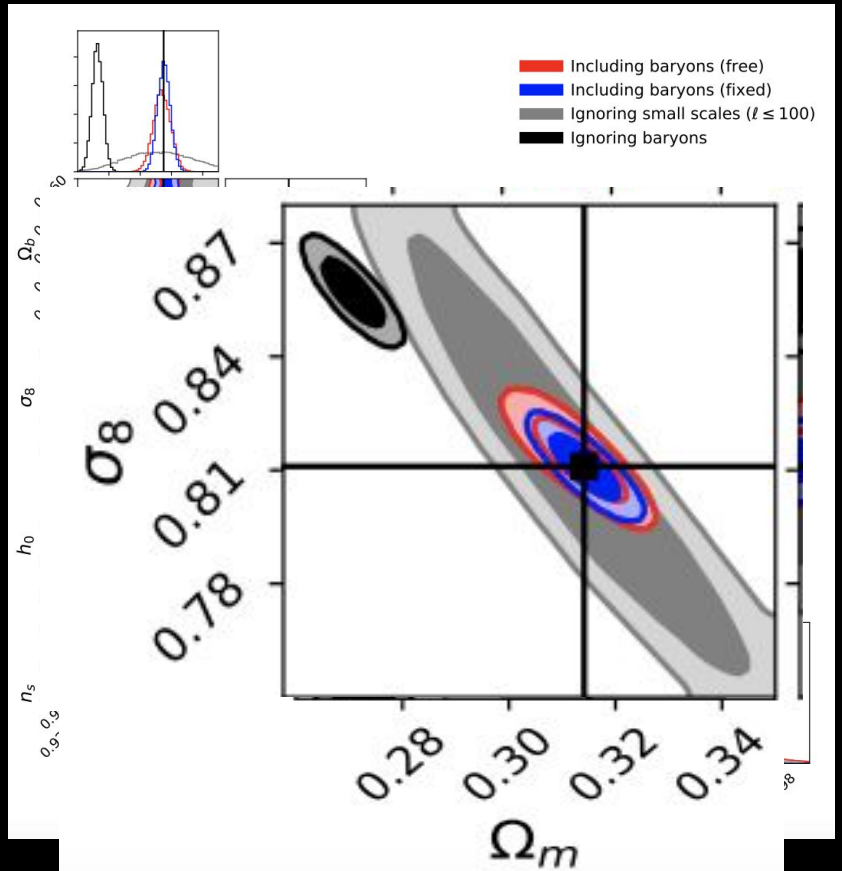
Schneider+2020

$$C_{ij}(\ell) = \int_0^{\chi_H} \frac{g_i(\chi) g_j(\chi)}{\chi^2} P_{\rm dmb}\left(\frac{\ell}{\chi}, z(\chi)\right) d\chi,$$

Parameter estimation

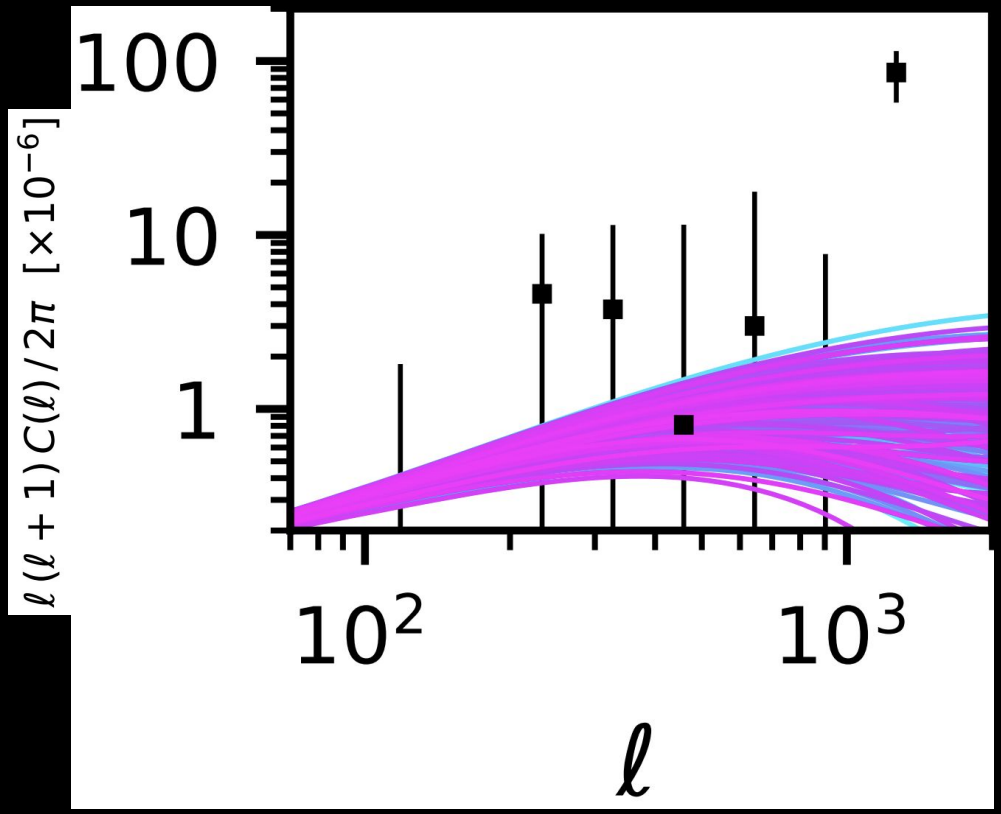


Constraints on cosmology



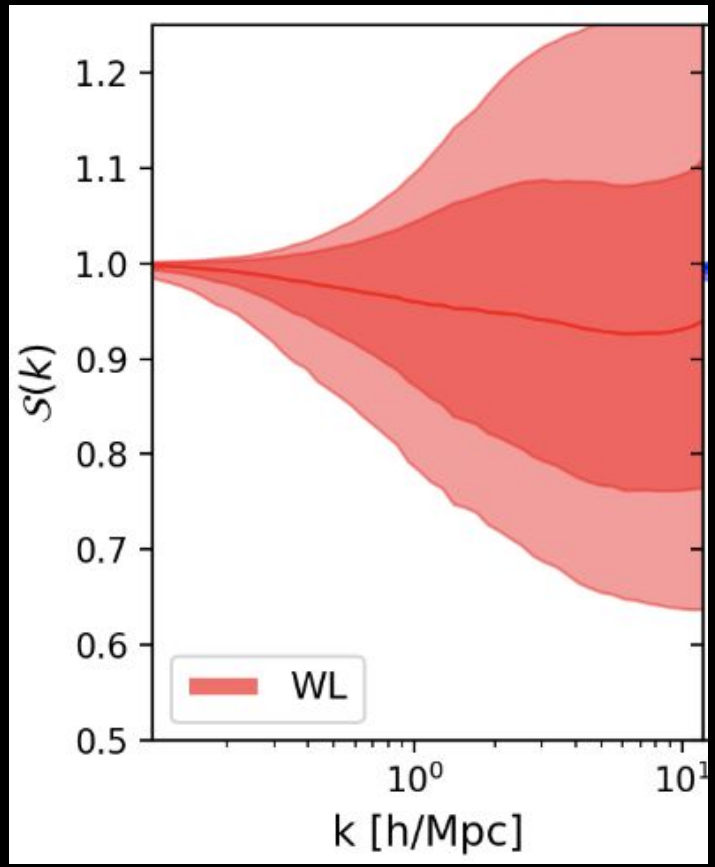
Schneider+2020

KiDS weak-lensing shear power spectrum



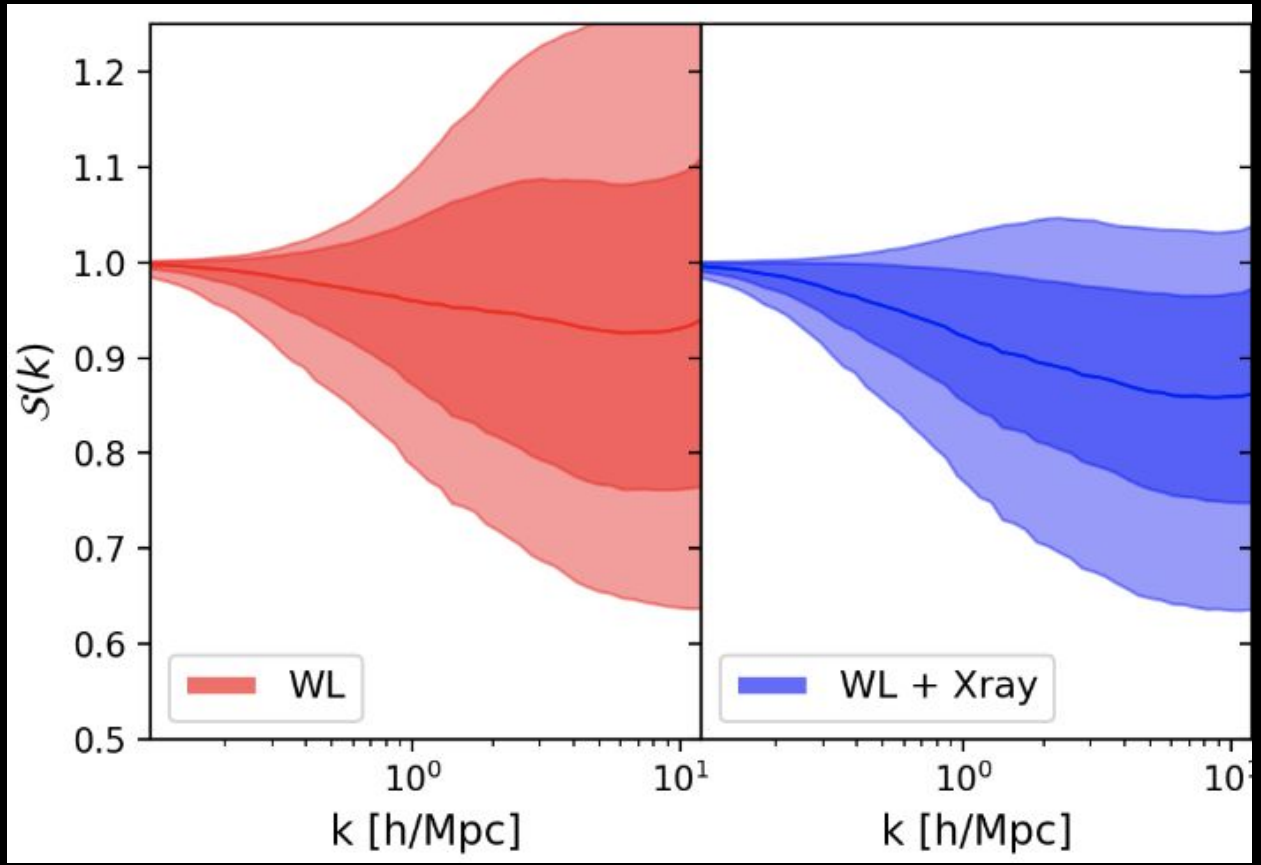
KiDS-1000 (Asgari+2021)
Schneider, Giri+ in prep

Constraints on baryonic effects with WL



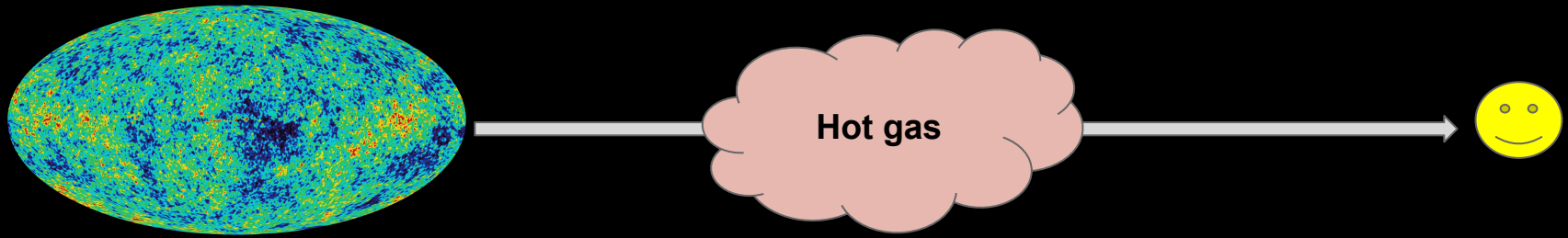
Schneider, Giri+ in prep

Constraints on baryonic effects with WL+Xray



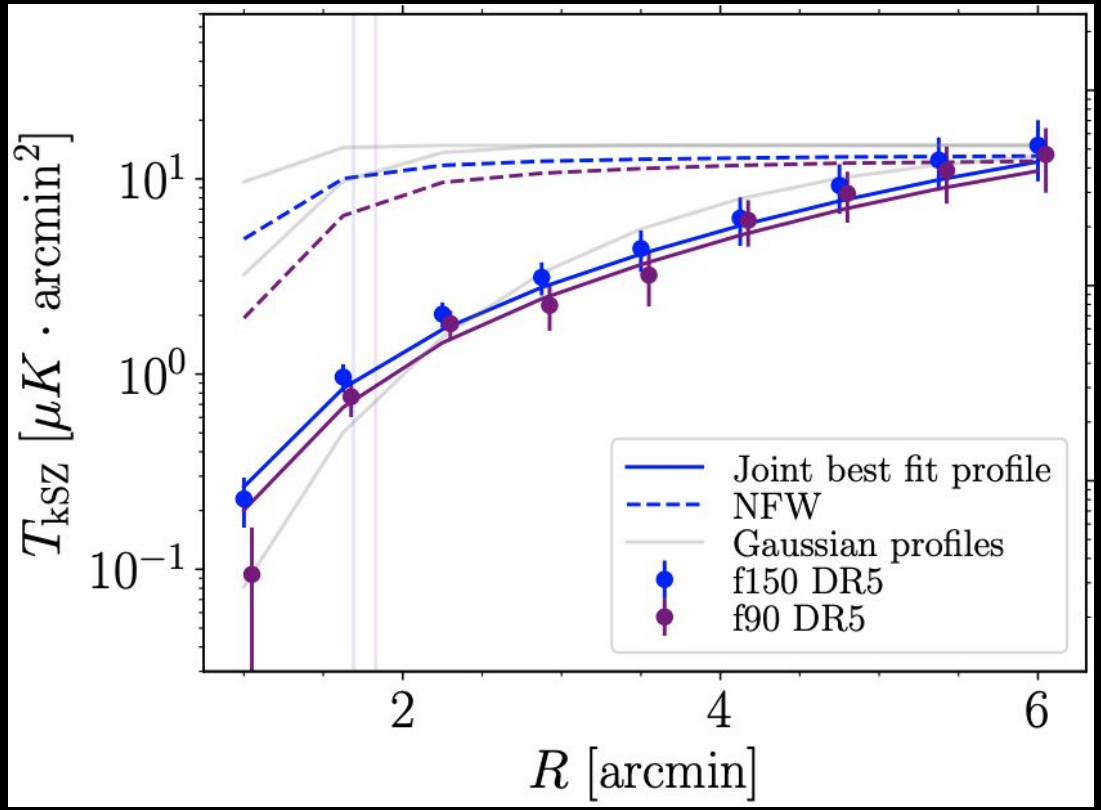
Schneider, Giri+ in prep

Kinetic Sunyaev-Zeldovich effect



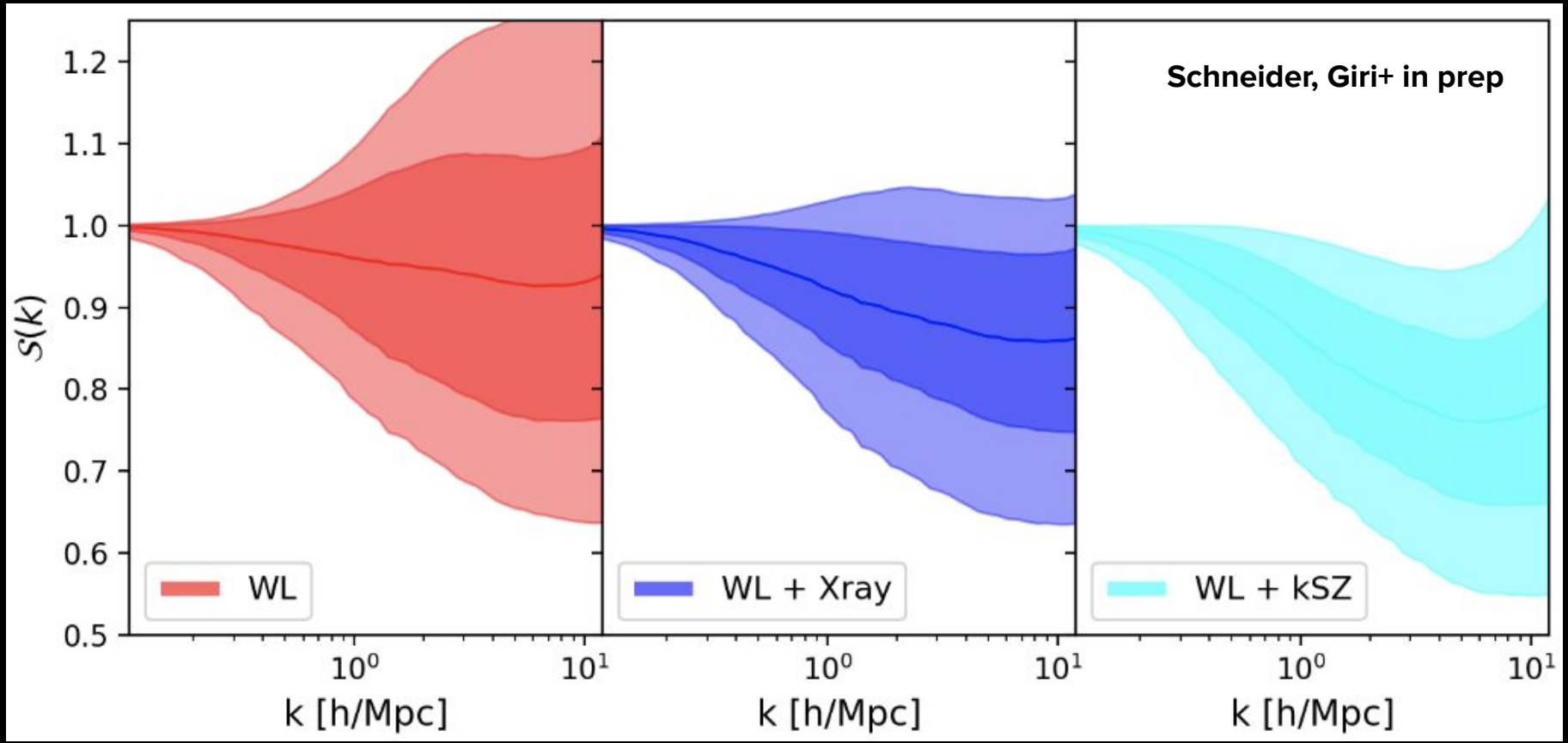
$$\frac{\delta T_{\rm kSZ}}{T_{\rm CMB}} = \tau_{\rm gal}\frac{v_r}{c}$$

kSZ from the Atacama Cosmology Telescope



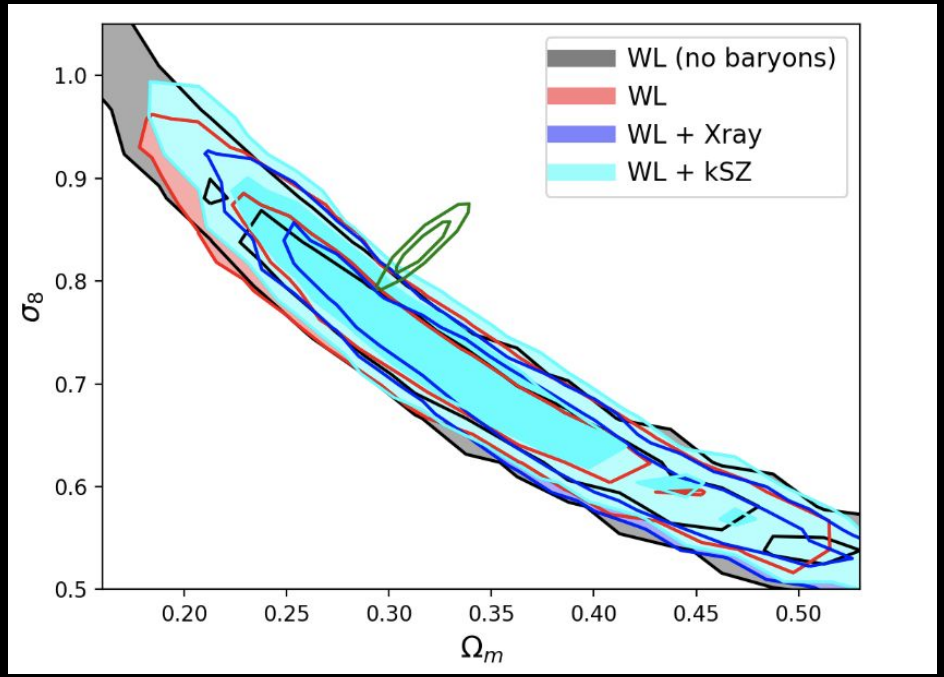
Schaan+2021
Amodeo+2021

Constraints on baryonic effects with WL+kSZ



σ_8 or S_8 tension

Schneider, Giri+ in prep



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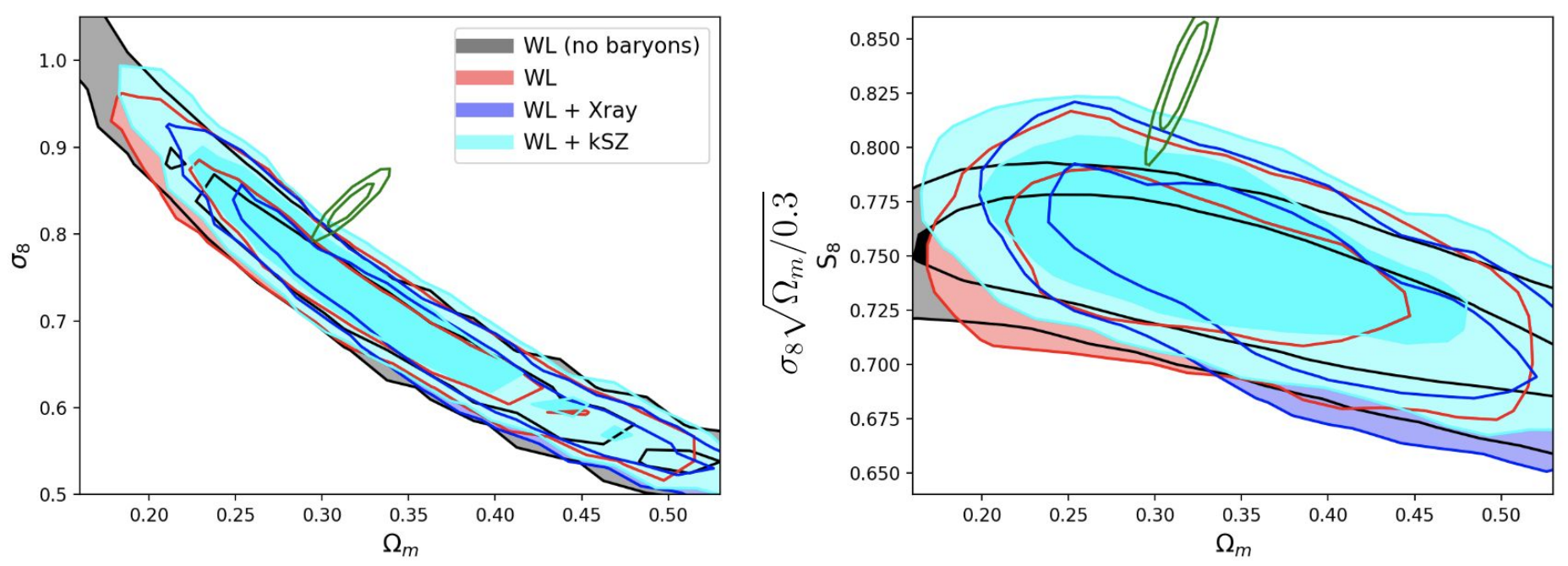
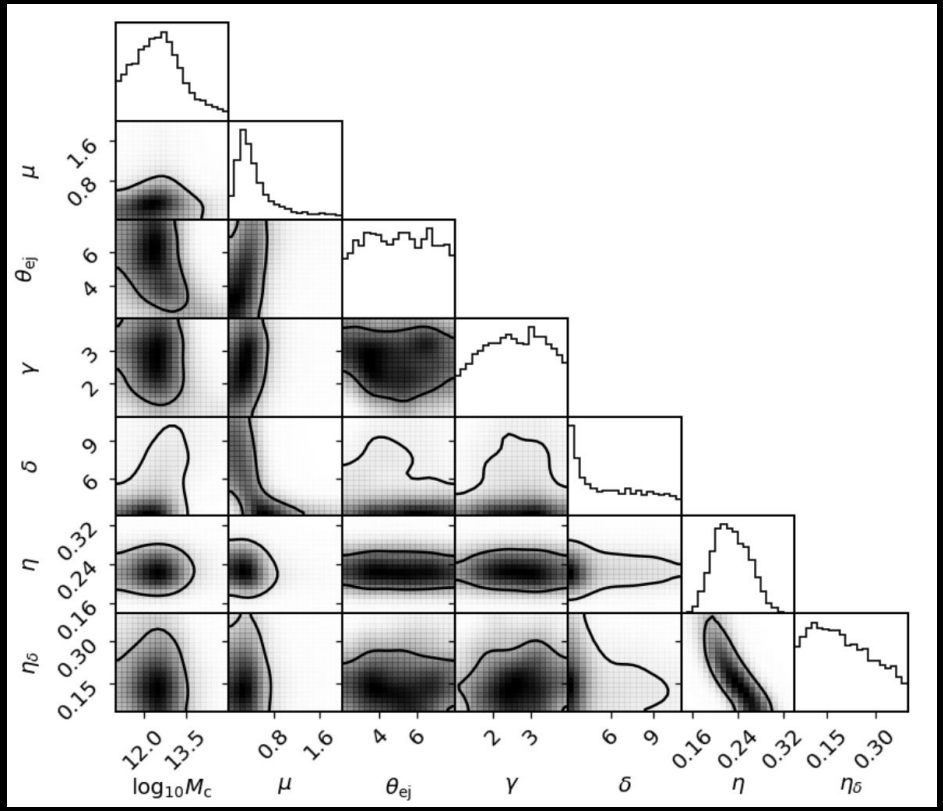
Schneider, Giri+ in prep



Summary

- Baryonification model is a fast modeling method to mimic baryonic feedback processes
- Not including the baryonic effects can bias our interpretation of cosmological data
- X-ray and kSZ observations of galaxy clusters suggest quite strong feedback
- Baryonic feedback can weaken the S_8 tension

X-ray constraints on baryonic parameters



Giri & Schneider (2021)