

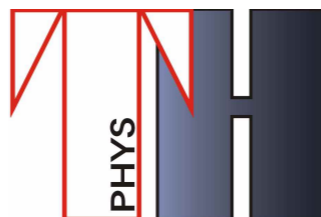
# Cosmological constraints on multi-interacting dark matter

Deanna C. Hooper

*Based on Becker, **DCH**, Kahlhoefer,  
Lesgourgues, Schöneberg (2010.04074)*

**PONT 2020**

**10<sup>th</sup> December 2020**



# Why interacting DM?

- The standard cosmological paradigm has several issues: small scale crisis,  $H_0$  and  $S_8$  tensions, EDGES anomaly
- Many alternatives to cold dark matter have been proposed to solve these, such as interacting dark matter
- Each type of interaction can provide different benefits
- We want to see if we can combine these effects
- We have implemented dark matter with multiple possible interaction channels in CLASS

# DM - baryon interactions

- We have implemented DM - baryon interactions with a power-law dependence on the relative bulk velocity (*Dvorkin et al. 1311.2937, Muñoz et al. 1509.00029, Slatyer et al. 1803.09734*)
- DM and baryons are assumed to be non-relativistic ( $m_{\text{DM}} \geq 1 \text{ MeV}$ ), and following a Maxwell velocity distribution
- We consider a momentum transfer cross section of the form

$$\sigma = \sigma_{\text{DM-b}} v^{n_b}$$

- We consider  $n_b = \{-4, 4\}$ . Well-motivated cases include  $n_b = 0$  (contact interactions) and  $n_b = -4$  (milicharged, may explain EDGES)

# DM - photon interactions

- We consider DM - photon interactions similar to the standard Thomson scattering (*Wilkinson et al. 1309.7588, Stadler et al. 1803.10229*)
- We assume the interactions are independent of temperature
- We parametrise the scattering cross section relative to the Thompson cross section as

$$u_{\text{DM}-\gamma} = \frac{\sigma_{\text{DM}-\gamma}}{\sigma_{\text{Th}}} \left( \frac{m_{\text{DM}}}{100\text{GeV}} \right)^{-1}$$

- Suppress the matter power spectrum, may solve the  $S_8$  tension

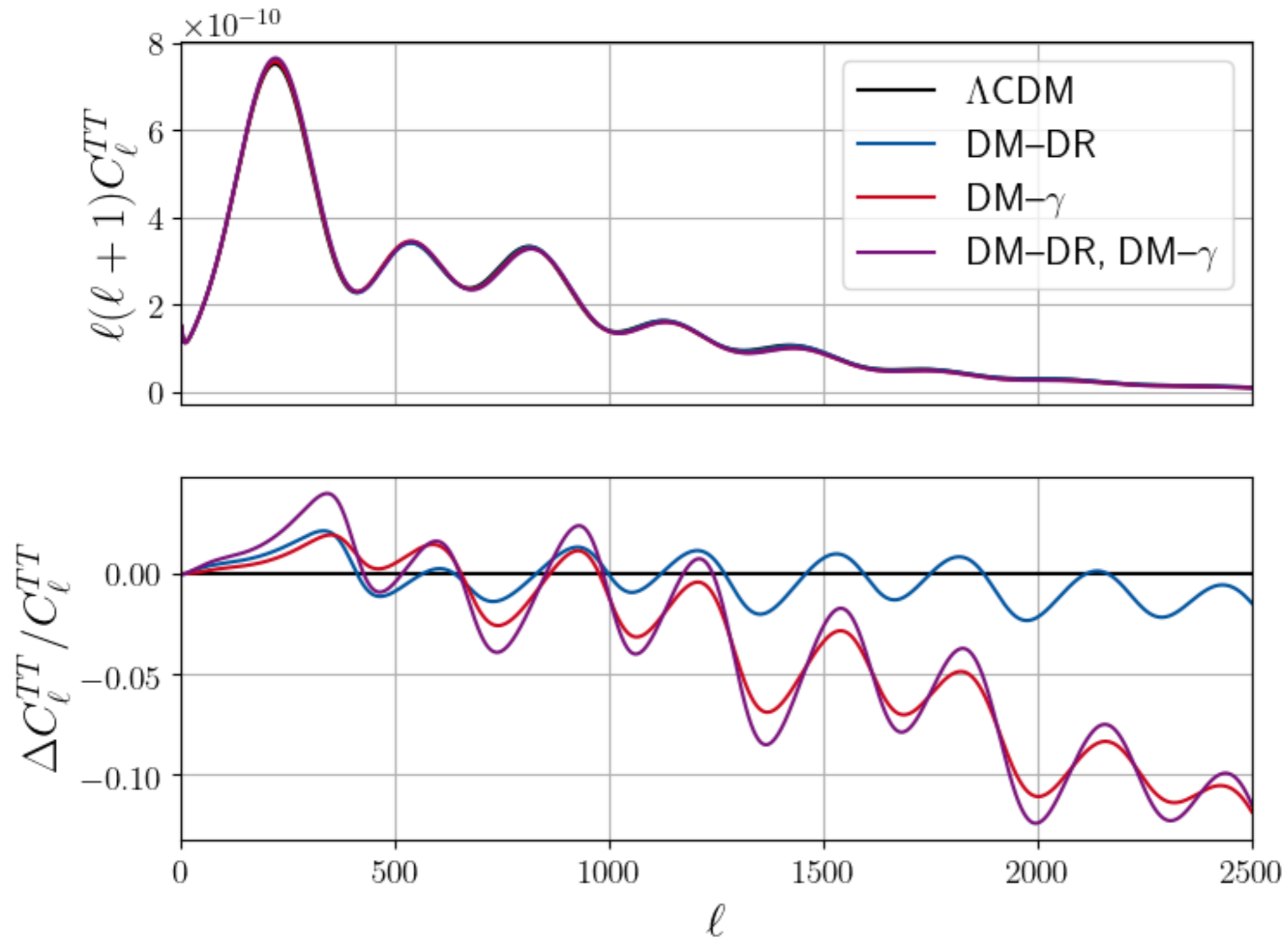
# DM - dark radiation interactions

- DM - DR interactions were implemented in CLASS v2.9 (*Archidiacono, DCH, et al. 1907.01496*)
- For general interactions, implementation based on the ETHOS formalism (*Cyr-Racine et al. 1512.05344*)
- DR is assumed to be massless and not interacting with SM particles. Can be either free-streaming or fluid-like
- Parameters: current momentum exchange rate  $\Gamma_{\text{DM-DR}}^0$ , amount of dark radiation  $N_{\text{DR}}$ , temperature dependence of scattering rate  $n_{\text{DR}}$
- Case of  $n_{\text{DR}} = 0$  may solve  $H_0$  and  $S_8$  tensions (*Buen-Abad et al. 1505.03542*)

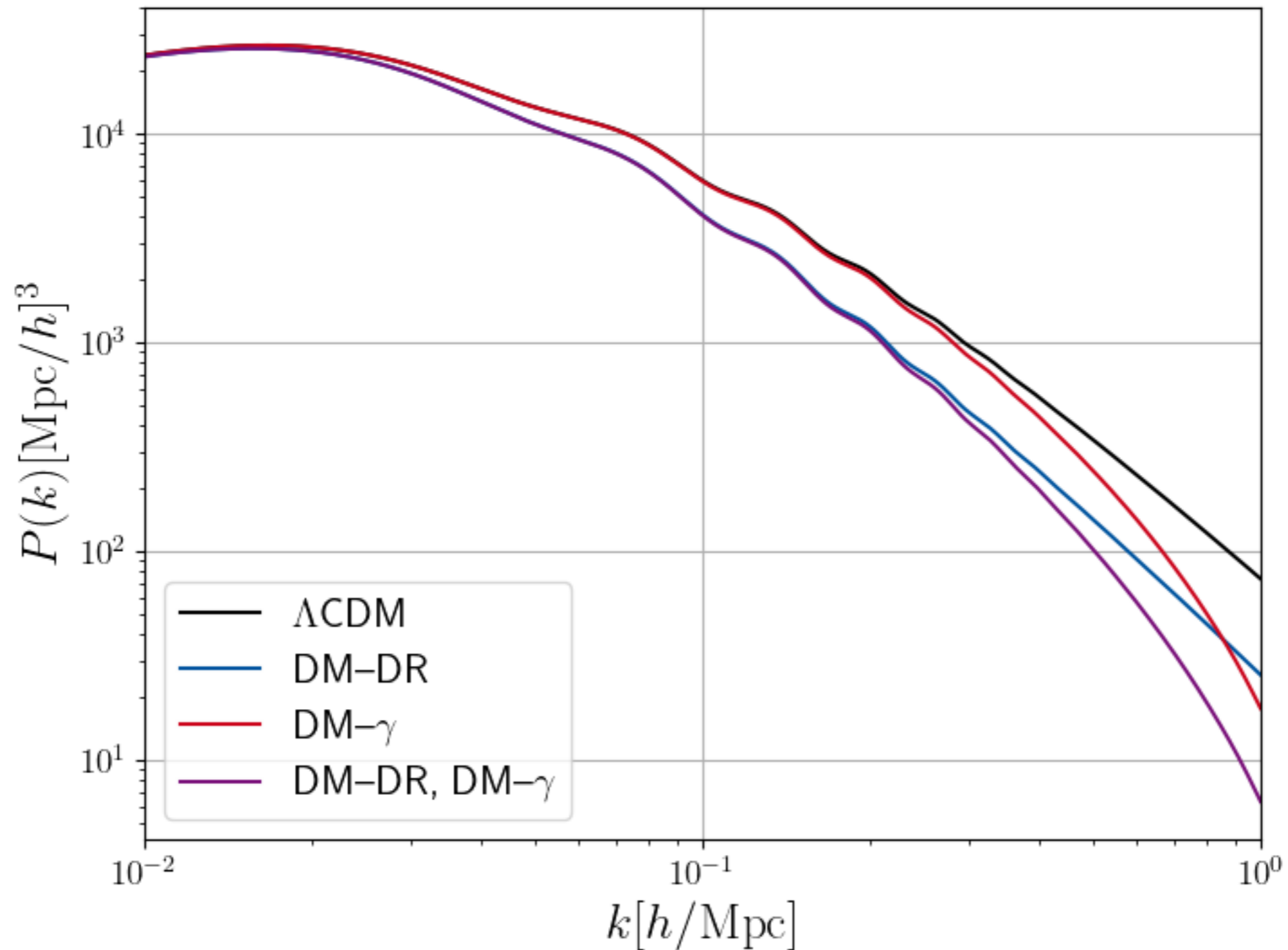
# Multi-interacting DM in CLASS

- We consider one dark matter species with multiple possible interaction channels
- CLASS now integrates the dark matter temperature together with normal matter temperature
- An analytic calculation of the decoupling redshifts ensures an early enough start without wasting computing time
- Special treatment for different tight coupling regimes
- This implementation allows us to study the imprint of multi-interacting dark matter on cosmological observables

# Effects on the observables



# Effects on the observables

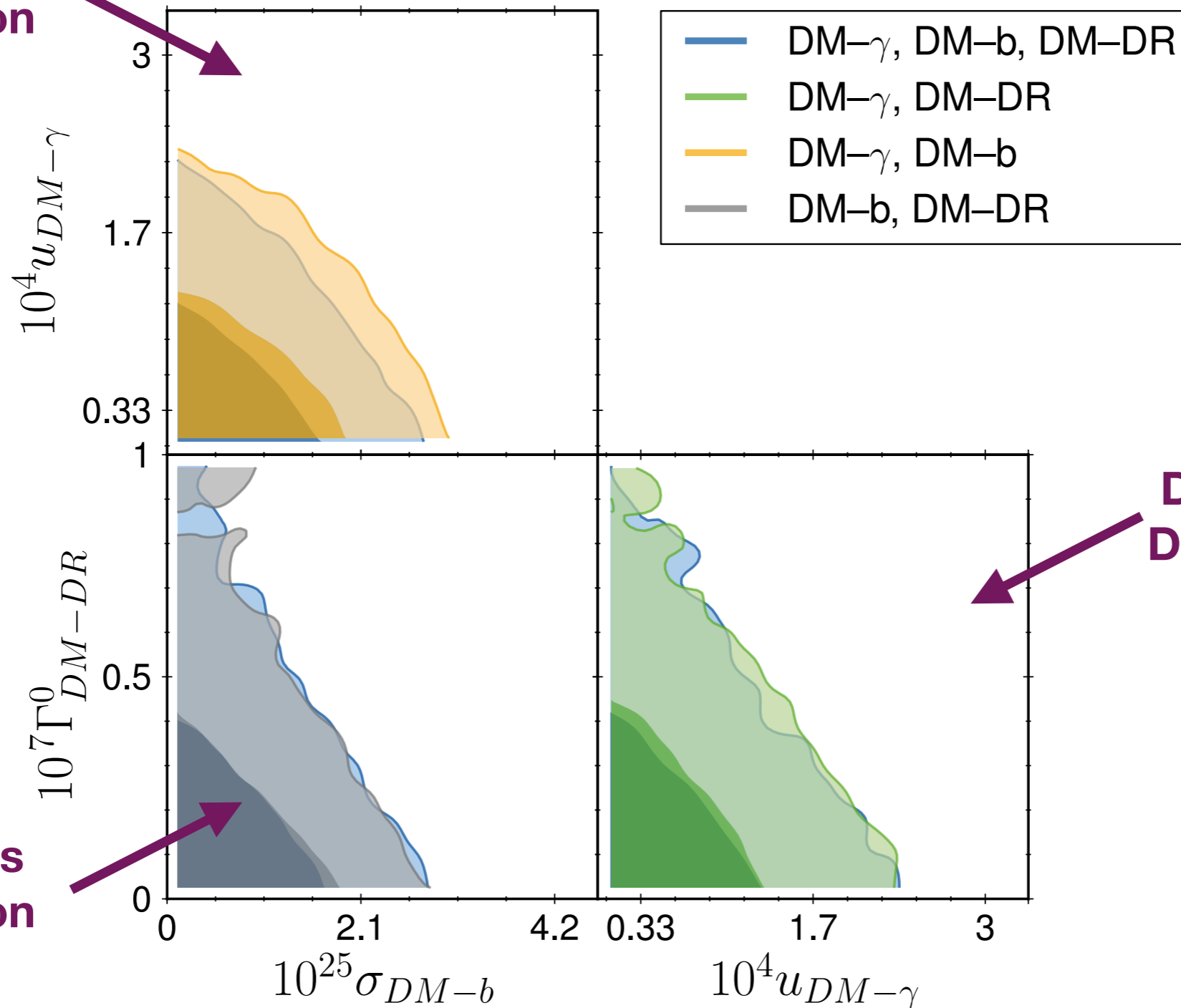




# IDM cross sections

Becker, *DCH*, et al. 2010.04074

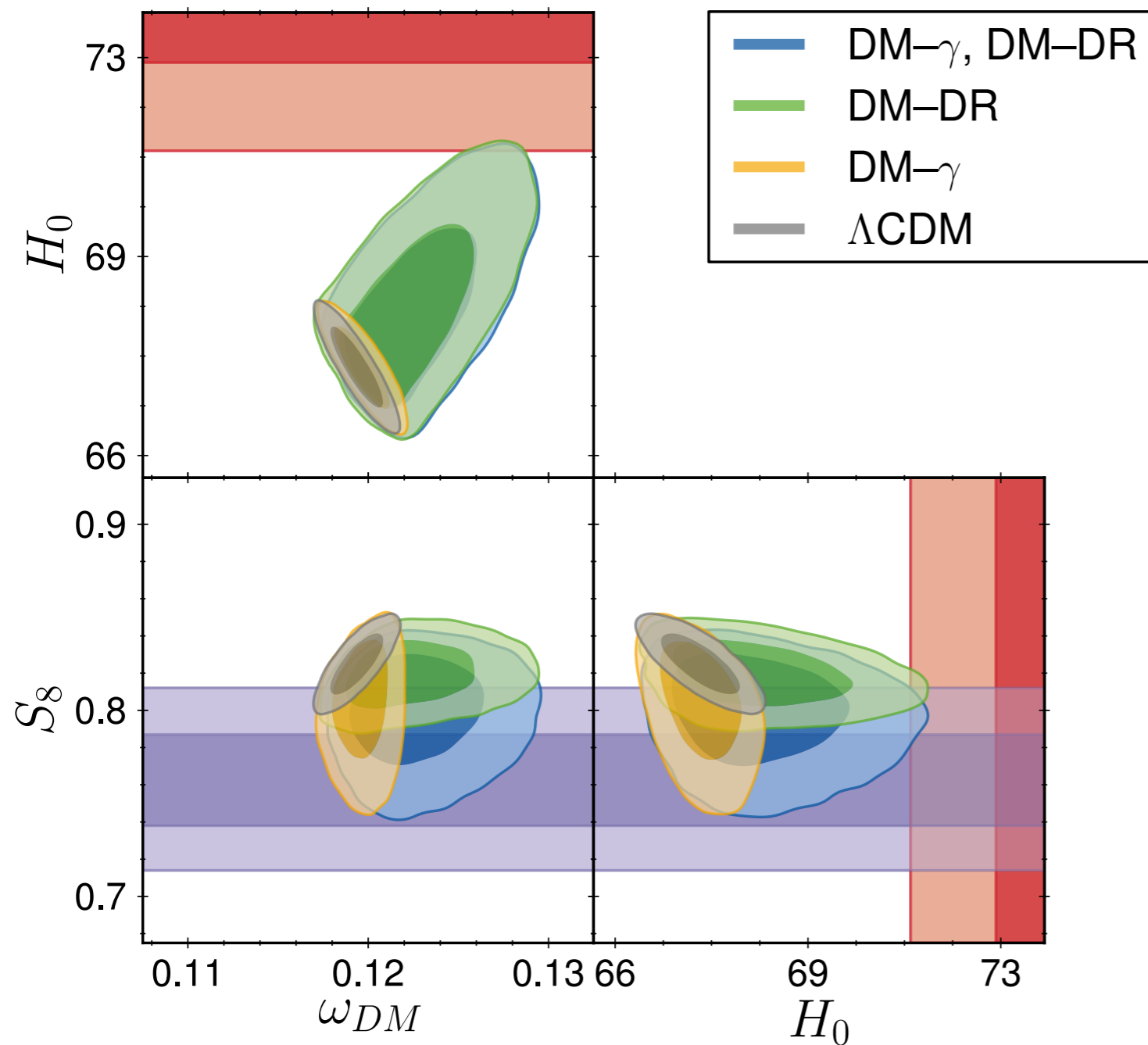
DM - photon vs  
DM - baryon



DM - DR vs  
DM - photon

DM - DR vs  
DM - baryon

# Cosmological tensions



Becker, **DCH**, et al. 2010.04074

- DM - photon interactions push to a lower  $S_8$  than  $\Lambda$ CDM
- DM - DR interactions push to higher  $H_0$  than  $\Lambda$ CDM
- Together they allow for both higher  $H_0$  and lower  $S_8$  values
- Comes at the expense of three new parameters

# Next step: Lyman- $\alpha$ Data

- Interacting DM models suppress structures on small scales: Lyman- $\alpha$  data crucial to constrain these models
- We have previously developed a new approach for using Lyman- $\alpha$  data without needing new hydrodynamical simulations  
*(Murgia et al. 1704.07838, Archidiacono, **DCH**, et al. 1907.01496)*
- We have already used this approach to constrain DM - dark radiation interactions
- We are in the final stages of extending this method to also cover DM - baryon and DM - photon interactions

# Summary

- We have developed a new version of CLASS: one dark matter species can have simultaneous interactions with baryons, photons, and dark radiation
- We have shown that the effects of different interactions on the cosmological observables are additive
- The existing bounds on the different interaction strengths are robust to the underlying model
- Such interacting models can solve both the  $H_0$  and  $S_8$  tensions, but at the expense of adding three new parameters
- Lyman- $\alpha$  data is expected to severely constrain these models
- The public release of our code as CLASS v3.1 paves the way for the study of various rich dark sectors

**Thank you for your attention**